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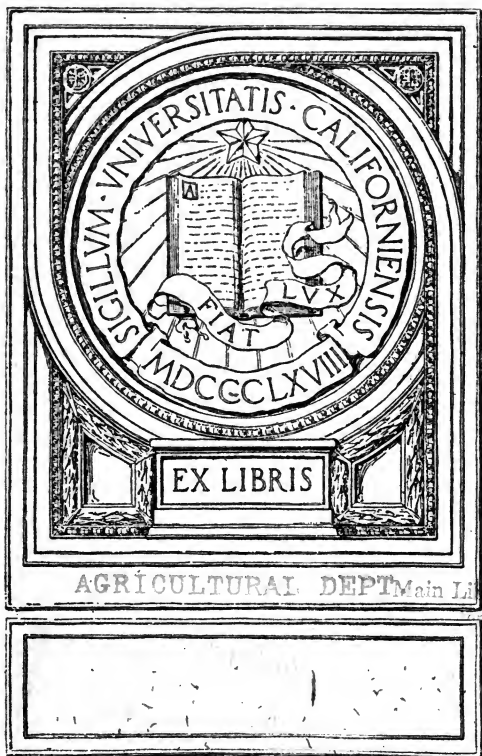
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PRINCIPLES OF MANURING

MANURES
AND THE
PRINCIPLES OF MANURING

BY

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TO
SIR JOHN BENNET LAWES, BART., D.C.L., LL.D., F.R.S.,
OF ROTHAMSTED,
AND
SIR J. HENRY GILBERT, M.A., LL.D., F.R.S.,
FORMERLY SIBTHORPIAN PROFESSOR OF RURAL ECONOMY,
UNIVERSITY OF OXFORD,
WHOSE FAMOUS INVESTIGATIONS DURING THE LAST FIFTY YEARS
HAVE SO LARGELY CONTRIBUTED TO BUILD UP
THE SCIENCE OF MANURING,
THIS WORK,
EMBODYING MANY OF THE ROTHAMSTED RESULTS,
IS DEDICATED.

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P R E F A C E.

WHEN the present work was first undertaken there were but few works in English dealing with its subject-matter, and hardly any which dealt with the question of Manuring at any length. During the last few years, however, owing to the greatly increased interest taken in agricultural education, the demand for agricultural scientific literature has called into existence quite a number of new works. Despite this fact, the author ventures to believe that the gap which the present treatise was originally designed to fill is still unfilled.

Of the importance of the subject all interested in agriculture are well aware. It is no exaggeration to say that the introduction of the practice of artificial manuring has revolutionised modern husbandry. Indeed, without the aid of artificial manures, arable farming, as at present carried out, would be impos-

sible. Fifty years ago the practice may be said to have been unknown; yet so widespread has it now become, that at the present time the capital invested in the manure trade in this country alone amounts to millions sterling. It need scarcely be pointed out, therefore, that a practice in which such vast monetary interests are involved is worthy of the most careful consideration by all students of agricultural science, as well as, it may be added, by political economists.

The aim of the present work is to supply in a concise and popular form the chief results of recent agricultural research on the question of soil fertility, and the nature and action of various manures. It makes no pretence to be an exhaustive treatise on the subject, and only contains those facts which seem to the author to have an important bearing on agricultural practice. In the treatment of its subject it may be said to stand midway between Professor Storer's recently published elaborate and excellent treatise on 'Agriculture in some of its Relations to Chemistry'—a work which is to be warmly recommended to all students of agricultural science, and to which the author would take this opportunity of acknowledging his indebtedness—and Dr J. M. H. Munro's admirable little work on 'Soils and Manures.'

In order to render the work as intelligible to the ordinary agricultural reader as possible, all tabular matter and matter of a more or less technical nature

have been relegated to the Appendices attached to each chapter.

The author's somewhat wide experience as a University Extension Lecturer, and as a Lecturer in connection with County Council schemes of agricultural education, during the last few years, induces him to believe that the work may be of especial value to those engaged in teaching agricultural science.

He has to express the deep obligation he is under, in common with all writers on Agricultural Chemistry, to the classic researches of Sir John Bennet Lawes, Bart., and Sir J. Henry Gilbert, now in progress for more than fifty years at Sir John Lawes' Experiment Station at Rothamsted. His debt of gratitude to these distinguished investigators has been still further increased by their kindness in permitting him to dedicate the work to them, and for having been good enough to read portions of the work in proof. In addition to the free use which has been made throughout the book of the results of these experiments, the last chapter contains, in a tabular form, a short epitome of some of the more important Rothamsted researches on the action of different manures.

To the numerous German and French works on the subject, more especially to Professor Heiden's encyclopædic '*Lehrbuch der Düngerlehre*' and the various writings of Dr Emil von Wolff, the author is further much indebted.

Among English works he would especially mention the assistance he has derived from the writings of Mr R. Warington, F.R.S., Professor S. W. Johnson, Professor Armsby, the late Dr Augustus Voelcker, and others. He would also tender his acknowledgments to the new edition of Stephens' 'Book of the Farm,' and he has to thank its editor, his friend Mr James Macdonald, Secretary to the Highland and Agricultural Society of Scotland, for having read parts of his proof-sheets.

It is also his pleasing duty to thank his friends Dr Bernard Dyer, Hon. Secretary of the Society of Public Analysts; Dr A. P. Aitken, Chemist to the Highland and Agricultural Society of Scotland; Professor Douglas Gilchrist of Bangor; Mr F. J. Cooke, late of Flitcham; Mr Hermann Voss of London; and Professor Wright of Glasgow, for having assisted him in the revision of proof-sheets.

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CONTENTS.

PART I.—HISTORICAL INTRODUCTION.

	PAGE
Beginning of agricultural chemistry	4
Early theories regarding plant-growth	4
Van Helmont	4
Digby	6
Duhamel and Stephen Hales	8
Jethro Tull	9
Charles Bonnet's discovery of source of plants' carbon	11
Researches of Priestley, Ingenhousz, Sénéquier, on assimilation of carbon	11-12
Publication of first English treatise by Earl Dundonald	13
Publication of Theodore de Saussure, 'Chemical Researches on Vegetation,' 1804	14
Theories on source of plant-nitrogen	15
Early experiments on this subject	16
Sir Humphry Davy's lectures (1802-1812)	17
State of agricultural chemistry in 1812	17
Beginning of Boussingault's researches (1834)	21
Publication of Liebig's first report to the British Association	24
Refutation of "humus" theory	26
Liebig's mineral theory	26
Liebig's theory of source of plants' nitrogen	27
Publication of Liebig's second report to British Association	30
Liebig's services to agricultural chemistry	31
Development of agricultural research in Germany	32
The Rothamsted Experiment Station	33

Sir J. B. Lawes and Sir J. H. Gilbert, the nature and value of their experiments	33
Review of the present state of our knowledge of plant-growth	36
Proximate composition of the plant	36
Fixation of carbon by plants	37
Action of light on plant-growth, Dr Siemens' experiments	38
Source of oxygen and hydrogen in the plant	39-40
Source of nitrogen in the plant	40
Relation of the free nitrogen to leguminous plants	42-44
Relation of nitrogen in organic forms, as ammonia salts, and nitrates to the plant	46-50
Nitrification and its conditions	51
Ash constituents of the plant	53
Methods of research for ascertaining essentialness of ash constituents of plants	53
(a) Artificial soils, (b) water-culture	53-55
Method in which plants absorb their food-constituents	55
Endosmosis	55
Retention by soils of plant-food	57
Causes of retention by soils of plant-food	59
Manuring	60
"Field" and "pot" experimentation	60

PART II.—PRINCIPLES OF MANURING.

CHAPTER I.—FERTILITY OF THE SOIL.

What constitutes fertility in a soil	65
I. Physical properties of a soil	66
Kinds of soils	67
Absorptive power for water of soils	67
Absorptive power for water of sand, clay, and humus	68
Fineness of particles of a soil	69
Limit of fineness of soil-particles	69
Importance of retentive power	70
Power of plants for absorbing water from a soil, experiments by Sachs	73
How to increase absorptive power of soils	74
Amount of water in a soil most favourable for plant growth	75
Hygroscopic power of soils	75
Capacity of soils for absorbing and retaining heat	76

Explanation of dew	77
Heat of soils	78
Heat in rotting farmyard manure	78
Causes of heat of fermentation	79
Influence of colour on heat-retaining power	80
Power of soils for absorbing gases	81
Gases found in soils	81
Variation in gas-absorbing power of soils	82
Absorption of nitrogen by soils	82
Requirements of plant-roots in a soil	83
Influence of tillage on number of plants in a certain area	86
Comparison of English and American farming	86
II. Chemical composition of a soil	87
Fertilising ingredients of a soil	87
Importance of <i>nitrogen, phosphoric acid, and potash</i> in a soil	88
Chemical condition of fertilising ingredients in soils	89
Amount of soluble fertilising ingredients in soils	90
Value of chemical analysis of soils	90
III. Biological properties of a soil	92
Bacteria of the soil	92
Recapitulation of Chapter I.	96

APPENDIX TO CHAPTER I.

NOTE

I. Table of absorptive power of soil substances by Schübler	98
II. Table of rate of evaporation of water in different soils by Schübler	99
III. Table of hygroscopic power of soils dried at 212° F. (Davy).	99
IV. Gases present in soil	100
V. Amount of plant-food in soils	100
VI. Chemical composition of the soil	101
VII. Forms in which plant-foods are present in the soil	107

CHAPTER II.—FUNCTIONS PERFORMED BY MANURES.

Etymological meaning of word manure	109
Definition of manures	110
Different classes of manures	111
Action of different classes of manures	113

CHAPTER III.—POSITION OF NITROGEN IN AGRICULTURE.

The Rothamsted experiments and the nitrogen question . . .	115
Different forms in which nitrogen exists in nature . . .	116
Relation of "free" nitrogen to the plant	117
Combined nitrogen in the air	118
Amount of combined nitrogen falling in the rain . . .	119
Nitrogen in the soil	120
Nitrogen in the subsoil	121
Nitrogen of surface-soil	121
Amount of nitrogen in the soil	123
Soils richest in nitrogen	123
Nature of the nitrogen in the soil	124
Organic nitrogen in the soil	125
Differences of surface and subsoil nitrogen	126
Nitrogen as ammonia in soils	127
Amount of ammonia in soils	127
Nitrogen present as nitrates in the soil	128
Position of nitric nitrogen in soil	128
Amount of nitrates in the soil	129
Amount of nitrates in fallow soils	129
Amount of nitrates in cropped soils	130
Amount of nitrates in manured wheat-soils	131
The sources of soil-nitrogen	131
Accumulation of soil-nitrogen under natural conditions .	133
Accumulation of nitrogen in pastures	134
Gain of nitrogen with leguminous crops	135
The fixation of "free" nitrogen	136
Influence of manures in increasing soil-nitrogen . . .	136
Sources of loss of nitrogen	137
Loss of nitrates by drainage	137
Prevention of loss of nitrogen by permanent pasture and "catch-cropping".	138
Other conditions diminishing loss of nitrates	139
Amount of loss of nitrogen by drainage	140
Loss of nitrogen in form of "free" nitrogen	141
Total amount of loss of nitrogen	142
Loss of nitrogen by retrogression	142
Artificial sources of loss of nitrogen	144
Amount of nitrogen removed in crops	144

Losses of nitrogen incurred on the farm	146
Loss in treatment of farmyard manure	146
Nitrogen removed in milk	147
Economics of the nitrogen question	147
Loss of nitrogen-compounds in the arts	148
Loss due to use of gunpowder	148
Loss due to sewage disposal	149
Our artificial nitrogen supply	150
Nitrate of soda and sulphate of ammonia	150
Peruvian guano	151
Bones	151
Other nitrogenous manures	152
Oil-seeds and oilcakes	153
Other imported sources of nitrogen	153
Conclusion	153

APPENDIX TO CHAPTER III.

NOTE.

I. Determination of the quantity of nitrogen supplied by rain, as ammonia and nitric acid, to an acre of land during one year	155
II. Nitrogen in soils at various depths	156
III. Nitrogen as nitrates in cropped soils receiving no nitrogenous manures, in lb. per acre (Rothamsted soils) . .	157
IV. Nitrogen as nitrates in Rothamsted soils	157
V. Examples of increase of nitrogen in Rothamsted soils laid down in pasture	158
VI. Loss by drainage of nitrates	158
VII. Examples of decrease of nitrogen in Rothamsted soils . .	159
VIII. Amount of drainage and nitrogen as nitrates in drainage-water from unmanured bare soil, 20 and 60 inches deep	160

CHAPTER IV.—NITRIFICATION.

Process of nitrification	161
Occurrence of nitrates in the soil	162
Nitre soils of India	162
Saltpetre plantations	163
Cause of nitrification	165
Ferments effecting nitrification	167
Appearance of nitrous organisms	168
Nitric organism	169

Difficulty in isolating them	169
Nitrifying organisms do not require organic matter . . .	169
Conditions favourable for nitrification—	
Presence of food-constituents	170
Presence of a salifiable base	171
Only takes place in slightly alkaline solutions	172
Action of gypsum on nitrification	173
Presence of oxygen	173
Temperature	175
Presence of a sufficient quantity of moisture	176
Absence of strong sunlight	176
Nitrifying organisms destroyed by poisons	176
Denitrification	177
Denitrification also effected by bacteria	178
Conditions favourable for denitrification	178
Takes place in water-logged soils	179
Distribution of the nitrifying organisms in the soil . . .	179
Depth down at which they occur	180
Action of plant-roots in promoting nitrification . . .	181
Nature of substances capable of nitrification	181
Rate at which nitrification takes place	183
Nitrification takes place chiefly during summer . . .	183
Process goes on most quickly in fallow fields	184
Laboratory experiments on rate of nitrification . . .	185
Certain portions of soil - nitrogen more easily nitrifiable than the rest	187
Rate of nitrification deduced from field experiments . .	187
Quantity of nitrates formed in the soils of fallow fields .	188
Position of nitrates depends on season	188
Nitrates in drainage-waters	188
Amount produced at different times of year	189
Nitrification of manures	190
Ammonia salts most easily nitrifiable	191
Sulphate of ammonia the most easily nitrifiable manure .	191
Rate of nitrification of other manures	192
Soils best suited for nitrification	192
Absence of nitrification in forest-soils	193
Important bearing of nitrification on agricultural practice .	193
Desirable to have soil covered with vegetation	194
Permanent pasture most economical condition of soil . .	194
Nitrification and rotation of crops	195

APPENDIX TO CHAPTER IV.

NOTE

I. Old theories of nitrification	196
II. Nitrification takes place in solutions devoid of organic matter	196
III. Oxidising power of micro-organisms in soils	197
IV. Effect of urine on nitrification in soils	197
V. Solution used by Professor Frankland in cultivating nitrificative micro-organisms	198
VI. Experiments by Boussingault on rate of nitrification	198
VII. Nitrogen as nitrates in Rothamsted soils after bare fallow in lb. per acre	198

CHAPTER V.—POSITION OF PHOSPHORIC ACID IN AGRICULTURE.

Occurrence of phosphoric acid in nature	199
Mineral sources of phosphoric acid	200
Apatite and phosphorite	200
Coprolites	201
Occurrence of phosphoric acid in guanos	202
Universal occurrence in common rocks	202
Occurrence in the soil	203
Condition in which phosphoric acid occurs in the soil	203
Occurrence in plants	204
Occurrence in animals	205
Sources of loss of phosphoric acid in agriculture	205
Loss of phosphoric acid by drainage	206
Artificial sources of loss of phosphoric acid	206
Amount of phosphoric acid removed in milk	207
Loss of phosphoric acid in treatment of farmyard manure	208
Loss of phosphoric acid in sewage	208
Sources of artificial gain of phosphoric acid	208

APPENDIX TO CHAPTER V.

NOTE

I. Composition of apatite (Voelcker)	210
II. Percentage of phosphoric acid in the commoner rocks	211

CHAPTER VI.—POSITION OF POTASH IN AGRICULTURE.

Potash of less importance than phosphoric acid	212
Occurrence of potash	213

Felspar and other potash minerals	213
Stassfurt salts	214
Occurrence of saltpetre	215
Occurrence of potash in the soil	215
Potash chiefly in insoluble condition in soils	216
Percentage of potash in plants and plant-ash	216
Occurrence of potash in animal tissue	217
Sources of loss of potash	217
Amount of potash removed in crops	218
Amount of potash removed in milk	218
Potash manures	218

APPENDIX TO CHAPTER VI.

NOTE

I. Amount of potash in different minerals	220
II. Quantity of potash obtained from 1000 lb. of different kinds of vegetation in the manufacture of potashes	220

PART III.—MANURES.

CHAPTER VII.—FARMYARD MANURE.

Variation in its composition	223
Made up of three classes of constituents	224
<i>Solid excreta—</i>	
Its nature	224
Difference in composition of the solid excreta of the different farm animals	224
Causes of this difference	225
Percentage of manurial ingredients in solid excreta of different animals	226
<i>Urine—</i>	
Its nature	228
Variation in its composition	229
Causes of this variation	229
Manurial value of the urine of the different farm animals	230
Percentage of the <i>organic matter, nitrogen, and mineral substances</i> in the food, voided in the solid excreta and urine	232
Comparison of manurial value of total excrements of the different farm animals	234

Nature of changes undergone by food in process of digestion	235
<i>Litter—</i>	
Its uses	236
<i>Straw</i> as litter, and its qualifications	237
Composition of different kinds of straw	238
<i>Loam</i> as litter	239
<i>Peat</i> as litter	240
Comparison of properties of <i>peat-moss</i> and <i>straw</i>	241
The <i>bracken-fern</i> as litter	241
<i>Dried leaves</i> as litter	242
Manures produced by the different animals—	
<i>Horse-manure—</i>	
Amount produced	243
Its nature and composition	243
Amount of straw used for litter	244
Sources of loss on keeping	245
How to prevent loss	245
Use of “fixers,” and the nature of their action	245
<i>Cow-manure—</i>	
Amount produced	248
Its nature and composition	248
Amount of straw used as litter	248
Sources of loss on keeping	249
Advantages of <i>short dung</i>	249
<i>Pig-manure—</i>	
Amount produced	250
Its nature and composition	250
Amount of straw used as litter	251
<i>Sheep-manure—</i>	
Amount produced	251
Nature and composition	251
Amount of straw used as litter	252
Methods of calculating amount of manure produced on the farm	252, note
Fermentation of farmyard manure—	
Action of <i>micro-organic</i> life in producing fermentation	255
Two classes of <i>bacteria</i> active in this work, <i>aerobies</i> and <i>anaerobies</i>	255
Conditions influencing fermentation—	
<i>Temperature</i>	256
<i>Openness to the air</i>	256

<i>Dampness</i>	257
<i>Composition of manure</i>	257
Products of fermentation	257
Analyses of farmyard manure—	
Dr Voelcker's experiments	259
Variation in composition	259
Amounts of <i>moisture, organic matter</i> (containing <i>nitrogen</i>), and <i>mineral matter</i>	260
Its manurial value compared with <i>nitrate of soda, sulphate</i> of <i>ammonia</i> , and <i>superphosphate</i>	260
Comparison of fresh and rotten manure—	
The nature and amount of loss sustained in the process of <i>rotting</i>	261
Ought manure to be applied <i>fresh</i> or <i>rotten</i> ?	262
Relative merits of <i>covered</i> and <i>uncovered</i> manure-heaps . .	263
Methods of application of farmyard manure to the field—	
Merits and demerits of the different methods	265
Setting it out in <i>heaps</i>	265
Spreading it <i>broadcast</i> , and letting it lie	266
Ploughing it in immediately	267
Value and function of farmyard manure—	
As a supplier of the necessary elements of plant-food . .	268
As a "universal" manure	269
Proportion in which <i>nitrogen, phosphoric acid</i> , and <i>potash</i> are required by crops	269
Proportion in which they are present in farmyard manure	270
Farmyard manure <i>poor in nitrogen</i>	270
Lawes' and Gilbert's experiments	271
How it may be best reinforced by the use of "artificial" .	271
Indirect value of farmyard manure as a supplier of <i>humus</i> to the soil	273
Its influence on soil-texture	273
Its influence in setting free inert fertilising matter in the soil	274
Rate at which farmyard manure ought to be applied . . .	275
Lasting nature of farmyard manure	276
Its economic value	276

APPENDIX TO CHAPTER VII.

NOTE

I. Difference in amount of excreta voided for food con- sumed	279
--	-----

NOTE

II. Solid excreta voided by sheep, oxen, and cows	279
III. Urine voided by sheep, oxen, and cows	280
IV. Percentage of food voided in the solid and liquid excrements	281
V. Pig excrements	281
VI. Manurial constituents in 1000 parts of ordinary foods .	282
VII. Analyses of stable-manure, made respectively with peat-moss litter and wheat-straw	283
VIII. Analyses of bracken	283
IX. Analyses of horse-manure	283
X. The nature of the chemical reactions of ammonia "fixers"	284
XI. Analyses of cow-manure	286
XII. Composition of fresh and rotten farmyard manure .	286
XIII. Comparison of fresh and rotten manure	288
XIV. Lord Kinnaird's experiments	289
XV. Drainings of manure-heaps	290
XVI. Amounts of potash and phosphoric acid removed by rotation from a Prussian morgen (.631 acre)	290
XVII. Composition of farmyard manure (fresh)	291
XVIII. The urine (quantity voided)	291

CHAPTER VIII.—GUANO.

Importance in agriculture	293
Influence on British farming	294
Influence of guano not wholly good	295
Value of guano as a manure	296
Origin and occurrence of guano	297
Variation in composition of different guanos	299
I. Nitrogenous guano—	
(a) Peruvian guano	300
Different deposits of Peruvian guano	301
Appearance, colour, and nature of Peruvian guano .	303
Composition of Peruvian guano	304
(b) Other nitrogenous manures: Angamos, Ichaboe .	306
II. Phosphatic guanos—	
Occurrence of phosphatic guanos	308
Inequality in composition of phosphatic guanos	309
"Dissolved" phosphatic guano	310
"Equalised" or "rectified" guano	311

The action of phosphatic guanos as manures	312
Proportion of fertilising constituents in guano	314
Mode of application of guanos	315
Quantity of guano to be used	317
Adulteration of guano	318
So-called guanos—	
Fish-guano	320
Value of fish-guano	322
Meat-meal guano	324
Value of meat-meal guano	324
Bat guano	325
Pigeon and fowl dung	325

APPENDIX TO CHAPTER VIII.

NOTE

I. Peruvian guano imported into United Kingdom, 1865-1893	327
II. Guano deposits of the world	327
III. Composition of concretionary nodules	328
IV. Table showing gradual deterioration of Peruvian guano, 1867-1881	329
V. Composition of different guanos	329
VI. Liebig's theory as to the action of oxalic acid in guano	330
VII. Analyses of dung of fowls, pigeons, ducks, and geese	331

CHAPTER IX.—NITRATE OF SODA.

Amount of exports	332
Date of discovery of nitrate deposits	333
The origin of nitrate deposits	334
Forbes and Darwin on the theory of their origin	335
Source of nitric acid in nitrate of soda	337
Guano theory of origin of nitrate of soda	337
Nitric acid in nitrate of soda probably derived from sea-weed	339
Appearance of nitrate-fields	340
The method of mining the nitrate of soda	341
Composition of <i>caliche</i>	342
Extent of the nitrate deposits	342
Composition and properties of nitrate of soda	343
Nitrate applied as a top-dressing	344
Nitrate of soda encourages deep roots	344

Is nitrate of soda an exhausting manure ?	345
Crops for which nitrate of soda is suited	346
Method of application of nitrate of soda	347
Importance of having a sufficiency of other fertilising constituents	348
Conclusions drawn	349

APPENDIX TO CHAPTER IX.

Total shipments from South America, 1830-1893 . . .	351
Total imports into Europe and United Kingdom, 1873-1892 .	351

CHAPTER X.—SULPHATE OF AMMONIA.

Value of ammonia as a manure	352
Sources of sulphate of ammonia	353
Ammonia from gas-works	353
Other sources	354
Composition, &c., of sulphate of ammonia	355
Application of sulphate of ammonia	356

APPENDIX TO CHAPTER X.

Production of sulphate of ammonia in United Kingdom, 1870-1892	358
---	-----

CHAPTER XI.—BONES.

Early use of bones	359
Different forms in which bones are used	360
Composition of bones	362
The organic matter of bones	363
The inorganic matter of bones	363
Treatment of bones	364
Action of bones	365
Dissolved bones	368
Crops suited for bones	368
Bone-ash	369
Bone-char or bone-black	369

APPENDIX TO CHAPTER XI.

NOTE

I. Analysis of bone-meal	371
II. Analysis of dissolved bones	371
III. Composition of bone-ash	372
IV. Composition of bone-char	372

CHAPTER XII.—MINERAL PHOSPHATES.

Coprolites	373
Canadian apatite or phosphorite	374
Estremadura or Spanish phosphates	375
Norwegian apatite	376
Charlestown or South Carolina phosphate	376
Belgian phosphate	377
Somme phosphate	378
Florida phosphate	378
Lahn phosphate	379
Bordeaux or French phosphate	379
Algerian phosphate	379
Crust guanos	379
Value of mineral phosphates as manures	380

APPENDIX TO CHAPTER XII.

Imports of phosphates	381
---------------------------------	-----

CHAPTER XIII.—SUPERPHOSPHATES.

Discovery of superphosphate by Liebig	382
Manufacture of superphosphate	383
Nature of the reaction taking place	385
Phosphates of lime	385
Reverted phosphate	389
Value of reverted phosphate	391
Composition of superphosphates	391
Action of superphosphates	392
Action of superphosphate sometimes unfavourable	395
Application of superphosphate	395
Value of insoluble phosphates	396
Rate at which superphosphate is applied	397

APPENDIX TO CHAPTER XIII.

NOTE

I. The formulæ, and molecular and percentage composition, of the different phosphates	398
II. Reactions of sulphuric acid and phosphate of lime	398
III. Table for conversion of soluble phosphate into insoluble phosphate	399
IV. Action of iron and alumina in causing reversion	399
V. Relative trade values of phosphoric acid in different manures	400

CHAPTER XIV.—THOMAS-PHOSPHATE OR
BASIC SLAG.

Its manufacture	401
Not at first used	403
Discovery of its value as a manure	403
Composition of basic slag	404
Processes for preparing slag	406
Solubility of basic slag	408
Darmstadt experiments with basic slag	410
Results of other experiments	413
Soils most suited for slag	414
Rate of application	414
Method of application	416

APPENDIX TO CHAPTER XIV.

Analysis of basic slag	417
----------------------------------	-----

CHAPTER XV.—POTASSIC MANURES.

Relative importance	418
Scottish soils supplied with potash	419
Sources of potassic manures	419
Stassfurt potash salts	420
Relative merits of sulphate and muriate of potash	421
Application of potash manures	422
Soils and crops suited for potash manures	423
Rate of application	423

CHAPTER XVI.—MINOR ARTIFICIAL MANURES.

Scutch	427
Shoddy and wool-waste	427
Soot	428

CHAPTER XVII.—SEWAGE AS A MANURE.

Irrigation	431
Effects of continued application of sewage	433
Intermittent irrigation	434
Crops suited for sewage	434
Treatment of sewage by precipitation, &c.	436
Value of sewage sludge	439

CHAPTER XVIII.—LIQUID MANURE 442

CHAPTER XIX.—COMPOSTS.

Farmyard manure a typical compost	446
Other composts	447

CHAPTER XX.—INDIRECT MANURES.

Lime	449
Antiquity of lime as a manure	449
Action of lime	449
Lime a necessary plant-food	450
Lime of abundant occurrence	452
Lime returned to the soil in ordinary agricultural practice	452
Different forms of lime	453
Caustic lime	453
Lime acts both mechanically and chemically	455
I. Mechanical functions of lime	455
Action on soil's texture	455
Lime renders light soils more cohesive	457
II. Chemical action of lime	457

III. Biological action of lime	459
Action of lime on nitrogenous organic matter	460
Recapitulation	461

CHAPTER XXI.—INDIRECT MANURES—GYPSUM, SALT, Etc.

Gypsum	462
Mode in which gypsum acts	462
Salt	465
Antiquity of the use of salt	465
Nature of its action	465
Salt not a necessary plant-food	466
Can soda replace potash?	466
Salt of universal occurrence	467
Special sources of salt	468
The action of salt	468
Mechanical action on soils	470
Solvent action	470
Best used in small quantities along with manures	472
Affects quality of crop	472
Rate of application	473

CHAPTER XXII.—THE APPLICATION OF MANURES.

Influence of manures in increasing soil-fertility	474
Influence of farmyard manure on the soil	475
Farmyard manure <i>v.</i> artificials	476
Farmyard manure not favourable to certain crops	477
Conditions determining the application of artificial manures	477
Nature of the manure	478
Nitrogenous manures	478
Phosphatic manures	480
Potash manures	480
Nature of soil	481
Nature of previous manuring	482
Nature of the crop	483
Amounts of fertilising ingredients removed from the soil by different crops	484
Capacity of crops for assimilating manures	486
Difference in root-systems of different crops	488

Period of growth	489
Variation in composition of crops	490
Absorption of plant-food	490
Fertilising ingredients lodge in the seed	491
Forms in which nitrogen exists in plants	491
Bearing of above on agricultural practice	492
Influence of excessive manuring of crops	492

CHAPTER XXIII.—MANURING OF THE COMMON FARM CROPS.

Cereals	493
Especially benefited by nitrogenous manures	494
Power of absorbing silicates	494
Barley	495
Period of growth	495
Most suitable soil	496
Farmyard manure not suitable	497
Importance of uniform manuring of barley	497
Norfolk experiments on barley	497
Proportion of grain to straw	498
Wheat	499
Rothamsted experiments	500
Continuous growth	500
Flitcham experiments	500
Oats	501
A very hardy crop	502
Require mixed nitrogenous manuring	502
Arendt's experiments	503
Avenine	503
Quantities of manures	504
Grass	504
Effect of manures on herbage of pastures	505
Influence of farmyard manure	506
Influence of soil and season on pastures	507
Manuring of meadow land	508
Bangor experiments	508
Norfolk experiments	509
Manuring of permanent pastures	509
Roots	510
Influence of manure on composition	512
Nitrogenous manures increase sugar	512

Amount of nitrogen recovered in increase of crop	513
Norfolk experiments	513
Manure for swedes	514
Highland Society's experiments	515
Manuring for rich crops of turnips	516
Experiments by the author on turnips	516
Potatoes	517
Highland Society's experiments	518
The Rothamsted experiments	519
Effect of farmyard manure	520
Manuring of potatoes in Jersey	521
The influence of manure on the composition	521
Leguminous crops	522
Leguminous plants benefit by potash	523
Nitrogenous manures may be hurtful	523
Clover sickness	524
Alternate wheat and bean rotation	524
Beans	525
Manure for beans	525
Relative value of manurial ingredients	526
Gypsum as a bean manure	526
Effect of manure on composition of crop	527
Peas	527
Hops	528
Cabbages	528

APPENDIX TO CHAPTER XXIII.

Experiments on bean-manuring	530
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CHAPTER XXIV.—ON THE METHOD OF APPLICATION,
AND ON THE MIXING OF MANURES.

Equal distribution of manures	531
Mixing manures	532
Risks of loss in mixtures	533
Loss of ammonia	533
Effects of lime on ammonia	535
Loss of nitric acid	536
Reversion of phosphates	537
Manurial ingredients should be applied separately	538

CHAPTER XXV.—ON THE VALUATION AND ANALYSIS OF MANURES.

Value of chemical analysis	539
Interpretation of chemical analysis	539
Nitrogen	540
Phosphoric acid	541
Importance of mechanical condition of phosphate	542
Potash	542
Other items in the chemical analysis of manures	543
Fertilisers and Feeding Stuffs Act	543
Different methods of valuing manures	544
Unit value of manurial ingredients	544
Intrinsic value of manures	545
Field experiments	545
Educational value of field experiments	547
Value of manures deduced from experiments	548
Value of unexhausted manures	549
Potential fertility of a soil	549
Tables of value of unexhausted manures	551

APPENDIX TO CHAPTER XXV.

NOTE

I. Factors for calculating compounds from manurial ingredients	553
II. Units for determining commercial value of manures and cash prices of manures	554, 555
III. Manurial value of nitrogen and potash in different substances	556
IV. Comparative manurial value of different forms of nitrogen and potash	557
V. Lawes' and Gilbert's tables for calculating unexhausted value of manures	559

CHAPTER XXVI.—THE ROTHAMSTED EXPERIMENTS.

Nature of experiments on crops and manures	561
Soil of Rothamsted	561
Table I. List of Rothamsted field experiments	562
Wheat experiments—	
Unmanured plots	562

Wheat grown continuously on same land (unmanured)	562
Table II. Results of first eight years	562
" III. Results of subsequent forty years	562
Table IV. Wheat grown continuously with farmyard manure (14 tons per annum)	564
" V. Wheat grown continuously with artificial manures	565
Table VI. Experiments on the growth of barley, forty years, 1852-91	566
" VII. Experiments on the growth of oats, 1869-78	567
" VIII. Experiments on root crops—swedish turnips	568, 569
" IX. Experiments on mangel-wurzel	568, 569
" X. Experiments with different manures on permanent meadow-land, thirty-six years, 1856-91	570
" XI. Experiments on the growth of potatoes—average for five seasons, 1876-80	571
" XII. Experiments on growth of potatoes (continued)—average for twelve seasons, 1881-92	572

INDEX	573
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PART I.

HISTORICAL INTRODUCTION



MANURES AND THE PRINCIPLES OF MANURING.

HISTORICAL INTRODUCTION.

AGRICULTURAL CHEMISTRY, like most branches of natural science, may be said to be entirely of modern growth. While it is true we have many old speculations on the subject, they can scarcely be said to possess much scientific value. The great questions which had first to be solved by the agricultural chemist were,—What is the food of plants? and,—What is the source of that food? The second of these two questions more easily admitted of answer than the first. The source of plant-food could only be the atmosphere or the soil. As the composition of the atmosphere, however, was not discovered till the close of last century, and the chemistry of the soil is a question which is still requiring much work

ere we shall be in possession of anything like a full knowledge of it, it will be at once obvious that the very fundamental conditions for a solution of the question were wanting. The beginning, then, of a true scientific agricultural chemistry may be said to date from the brilliant discoveries associated with the names of Priestley, Scheele, Lavoisier, Cavendish, and Black—that is, towards the close of last century.

Early Theories on Source of Plant-food.

While this is so, and while we must regard the early attempts made towards solving this question as being, for the most part, of little scientific value, it is not without interest, from the historical point of view, to glance briefly at some of these old interesting speculations.

The Aristotelian doctrine, regarding the possibility of dividing matter into the so-called four primary elements, *fire, air, earth, and water*, which obtained in one form or another till the birth of modern chemistry, had naturally an important influence on these early theories.

Van Helmont's Theory.

Among the earliest and most important attempts made to solve the problem of plant-growth was that by Jean Baptiste Van Helmont, one of the best known of the alchemists, who flourished about the beginning of the seventeenth century. Van Helmont believed

that he had proved by a conclusive experiment that all the products of vegetables were capable of being generated from water. The details of this classical experiment were as follows:—

“He took a given weight of dry soil—200 lb.—and into this soil he planted a willow-tree that weighed 5 lb., and he watered this carefully from time to time with pure rain-water, taking care to prevent any dust or dirt falling on to the earth in which the plant grew. He allowed this to go on growing for five years, and at the end of that period, thinking his experiment had been conducted sufficiently long, he pulled up his tree by the roots, shook all the earth off, dried the earth again, weighed the earth and weighed the plant. He found that the plant now weighed 169 lb. 3 ounces, whereas the weight of the soil remained very nearly what it was—about 200 lb. It had only lost 2 ounces in weight.”¹

The conclusion, therefore, come to by Van Helmont was that the source of plant-food was *water*.²

¹ The History of the Chemical Elements. By Sir Henry E. Roscoe, F.R.S. (Wm. Collins, Sons, & Co.)

² Van Helmont's science was, however, of an extremely rudimentary nature, as may be evidenced by the belief he entertained that the smells which arise from the bottom of morasses produce frogs, slugs, leeches, and other things; as well as by the following recipe which he gave for the production of a pot of mice: “Press a dirty shirt into the orifice of a vessel containing a little corn, after about twenty-one days the ferment proceeding from the dirty shirt, modified by the odour of the corn, effects a transmutation of the wheat into mice.” The crowning point in this recipe, however, lay in the fact that he

Digby's Theory.

Some fifty years later an extremely interesting book was published bearing the following title: 'A Discourse concerning the Vegetation of Plants, spoken by Sir Kenelm Digby, at Gresham College, on the 23d of January 1660. (At a meeting of the Society for promoting Philosophical Knowledge by Experiments. London: Printed for John Williams, in Little Britain, over against St Botolph's Church, 1669.)' The author attributes plant-growth to the influence of a *balsam* which the air contains. This book is especially interesting as containing the earliest recognition of the value of saltpetre as a manure. The following is an extract from this interesting old work:—

"The sickness, and at last the death of a plant, in its natural course, proceeds from the want of that balsamick saline juice; which, I have said, makes it swell, germinate, and augment itself. This want may proceed either from a destitution of it in the place where the plant grows, as when it is in a barren soil or bad air, or from a defect in the plant itself, that hath not vigour sufficient to attract it, though it be within the sphere of it; as when the root has become

asserted that he had himself witnessed the fact, and, as an interesting and corroborative detail, he added that the mice were born full-grown. See 'Louis Pasteur: His Life and Labours.' By his Son-in-law. Translated by Lady Claud Hamilton. (Longmans, Green, & Co.) P. 89.

so hard, obstructed and cold, as that it hath lost its vegetable functions. Now, both these may be remedy'd, in a great measure, by one and the same physick. . . . The watering of soils with cold hungray springs doth little good ; whereas muddy saline waters brought to overflow a piece of ground enrich it much. But above all, well-digested dew makes all plants luxuriate and prosper most. Now what may it be that endues these liquors with such prolifick virtue ? The meer water which is common to them all, cannot be it ; there must be something else enclosed within it, to which the water serves but for a vehicle. Examine it by spagyric art, and you will find that it is nothing else than a *nitrous salt*, which is dilated in the water. It is this salt which gives fœcundity to all things : and from this salt (rightly understood) not only all vegetables, but also all minerals draw their origine. By the help of plain *salt-peter*, dilated in water and mingled with some other fit earthy substance, that may familiarize it a little with the corn into which I endeavoured to introduce it, I have made the barrenest ground far out-go the richest, in giving a prodigiously plentiful harvest. I have seen hemp-seed soaked in this liquor, that hath in due time made such plants arise, as, for the tallness and hardness of them, seemed rather to be coppice-wood of fourteen years' growth at least, than plain hemp. The fathers of the Christian doctrine at Paris still keep by them for a monument (and indeed it is an admirable one)

a plant of barley consisting of 249 stalks, springing from one root or grain of barley ; in which they counted above 18,000 grains or seeds of barley. But do you think that it is barely the salt-peter, imbibed into the seed or root, which causeth this fertility ? no : that would be soon exhausted and could not furnish matter to so vast a progeny. The salt-peter there is like a magnet, which attracts a like salt which fœcundates the air, and gave cause to the Cosmopolite to say there is in the air a hidden food of life.”¹

Duhamel and Hales.

The names of the French writer, Duhamel, and of the English, Stephen Hales, may be mentioned in passing as authors of works bearing on the question of vegetable physiology. Both of these writers flourished about the middle of the eighteenth century. The writings of the former contained much valuable information on the effects of grafting, motion of sap, and influence of light on vegetable growth, and also the results of experiments which the author had carried out on the influence of treating plants with certain substances. ‘*Statistical Essays, containing Vegetable Statics ; or an Account of some Statistical Experiments on the Sap of Vegetables, by Stephen Hales, D.D.*’ (2

¹ He then goes on to relate a number of experiments by Cornelius Drebel and Albertus Magnus, showing the refreshing power of this balsam, and then those of Quercitan with roses and other flowers, and his own with nettles.

vols.), was published in London in 1738; and contained, as will be seen from its title, records of experiments of very much the same nature as those of Duhamel.

Jethro Tull's Theory.

Some reference may be made to a theory which created a considerable amount of interest when it was first published—viz., that of Jethro Tull. The chief value of Tull's contribution to the subject of agricultural science was, that he emphasised the importance of tillage operations by putting forward a theory to account for the fact, universally recognised, that the more thoroughly a soil was tilled, the more luxuriant the crops would be. As Tull's theory had a very considerable influence in stirring up interest in many of the most important problems in agricultural chemistry, and as it contained in itself much, the value of which we have only of late years come to understand, a brief statement of this theory may not be without interest.

According to Tull the food of plants consists of the particles of the soil. These particles, however, must be rendered very minute before they become available for the plant, which absorbs them by means of its rootlets. This pulverisation of the soil goes on in nature independently of the farmer, but only very slowly, and the farmer has therefore to hasten it on by means of tillage operations. The more efficiently these operations are carried on, the more abundant will the supply

of plant-food be rendered in the soil. He consequently introduced and advocated the system of horse-hoe husbandry. This theory, he informs us, was suggested to him by the custom, which he had noticed on the Continent, of growing vines in rows, and hoeing the intervals between these rows from time to time. The excellent results which followed this mode of cultivation induced him to adopt it in England for his farm crops. He accordingly sowed his crops in rows or ridges, wide enough apart to admit of thorough tillage of the intervals by ploughing as well as by hand-hoeing. This he continued until the plant had reached maturity. As to the exact width of the interval most suitable, he made a large number of experiments. At first, in the cultivation of wheat, he made this interval six feet wide; but latterly he adopted an interval of lesser width, that finally arrived at being between four and five feet. He likewise experimented on each separate ridge as to which was the best number of rows of wheat to be sown, latterly adopting, as most convenient, two rows at ten inches apart. The great success which he met with in this system of cultivation induced him to publish the results of his experiments in his famous work, 'Horse-Hoeing Husbandry.'

While Tull's theory was based on principles at heart thoroughly sound, he was carried away by his personal success into drawing unwarrantable deductions. Thus he came to the conclusion that rotation

of crops was unnecessary, provided that a thorough system of tillage was carried out. Manures also, according to him, might be entirely dispensed with under his system of cultivation, for the true function of all manures is to aid in the pulverisation of the soil by fermentation.

The first really valuable scientific facts contributed to the science were made by Priestley, Bonnet, Ingenhousz, and Sénéquier.

Discovery of the Source of Plants' Carbon.

To Charles Bonnet (1720-1793), a Swiss naturalist, is due the credit of having made the first contribution to a discovery of very great importance—viz., the true source of the *carbon*, which we now know forms so large a portion of the plant-substance. Bonnet, who had devoted himself to the question of the function of leaves, noticed that when these were immersed in water bubbles were seen, after a time, to collect on their surface. De la Hire, it ought to be pointed out, had noticed this same fact about sixty years earlier. It was left to Priestley, however, to identify these bubbles with the gas he had a short time previously discovered—viz., oxygen. Priestley had observed, about this time, the interesting fact that plants possessed the power of purifying air vitiated by the presence of animal life.¹ The

¹ Priestley, however, did not realise that *carbonic acid gas* was a necessary plant-food; on the contrary, he considered it to have a

next step in this highly interesting and important discovery was taken by John Ingenhousz (1730-1799), an eminent physician and natural philosopher. In 1779, Ingenhousz published a work in London entitled 'Experiments on Vegetables.' In it he gives the results of some important experiments he had made on the question already investigated by Bonnet and Priestley. These experiments proved that plant-leaves only gave up their oxygen in the presence of sunlight. In 1782 he published another work on 'The Influence of the Vegetable Kingdom on the Animal Creation.'¹

The source of the gas, which Bonnet had first noticed to be given off from plant-leaves, Priestley had identified as oxygen, and Ingenhousz had proved to be only given off under the influence of the sun's rays, was finally shown by a Swiss naturalist, Jean S  n  bier² (1742-1809), to be the *carbonic acid gas* in the air, which the plant absorbed and decomposed, giving out the oxygen and assimilating the carbon.

deleterious action on plant-growth. Percival was really the first to point out that carbonic acid gas was a plant-food.

¹ It is recorded as an instance of the scientific enthusiasm of the man, that he was wont to carry about with him bottles containing oxygen, which he had obtained from cabbage-leaves, as also coils of iron wire, with which he could illustrate the brilliant combustion which ensued on burning the latter in oxygen gas.

² For a full account of S  n  bier's researches, see 'Physiologie v  g  tale, contenant une description des organes des plantes, et une exposition des ph  nomenes produits par leur organisation, par Jean S  n  bier.' (5 tomes. Gen  ve, 1800.)

Publication of First English Treatise on Agricultural Chemistry.

In 1795, a book dealing with the relations between chemistry and agriculture was published. This work was written by a Scottish nobleman, the Earl of Dundonald, and possesses especial interest from the fact that it is the first book in the English language on agricultural chemistry. The full title is as follows: 'A Treatise showing the Intimate Connection that subsists between Agriculture and Chemistry.'

In his introduction the author says: "The slow progress which agriculture has hitherto made as a science is to be ascribed to a want of education on the part of the cultivators of the soil, and to a want of knowledge, in such authors as have written on agriculture, of the intimate connection that subsists between the science and that of chemistry. Indeed, there is no operation or process not merely mechanical that does not depend on chemistry, which is defined to be a knowledge of the properties of bodies, and of the effects resulting from their different combinations."

In quoting this passage Professor S. W. Johnson remarks:¹ "Earl Dundonald could not fail to see that chemistry was ere long to open a splendid future for the ancient art that had always been and always will be the prime supporter of the nations. But when he

¹ How Crops Grow. By Professor S. W. Johnson. Macmillan & Co. (Introduction, p. 4.)

wrote, how feeble was the light that chemistry could throw upon the fundamental questions of agricultural science! The chemical nature of the atmosphere was then a discovery of barely twenty years' standing. The composition of water had been known but twelve years. The only account of the composition of plants that Earl Dundonald could give was the following: 'Vegetables consist of mucilaginous matter, resinous matter, matter analogous to that of animals, and some proportion of oil. . . . Besides these, vegetables contain earthy matters, formerly held in solution in the newly-taken-in juices of the growing vegetables.' To be sure, he explains by mentioning in subsequent pages that starch belongs to the mucilaginous matter, and that on analysis by fire vegetables yield soluble alkaline salts and insoluble phosphate of lime. But these salts, he held, were formed in the process of burning, their lime excepted; and the fact of their being taken from the soil and constituting the indispensable food of plants, his lordship was unacquainted with. The gist of agricultural chemistry with him was, that plants 'are composed of gases with a small proportion of calcareous matter; for although this discovery may appear to be of small moment to the practical farmer, yet it is well deserving of his attention and notice.'"

De Saussure.

The year 1804 witnessed the publication of by far the most important contribution made to the science

up till this time. This was 'Recherches Chimique sur la Végétation,' by Theodore de Saussure, one of the most illustrious agricultural chemists of the century. De Saussure was the first to draw attention to the mineral or ash constituents of the plant; and thus anticipate, to a certain extent, the subsequent famous "mineral" theory of the great Liebig. The French chemist maintained that these ash ingredients were essential; and that without them plant-life was impossible. He also adduced fresh experiments of his own in support of the theory, based on the experiments of Bonnet, Priestley, Ingenhousz, and Sénécier, that plants obtain their carbon from the carbonic acid gas in the air, under the influence of the sunlight. He was of opinion that the *hydrogen* and *oxygen* of the plant were, probably, chiefly derived from water. He showed that by far the largest portion of the plant's substance was derived from the air and from water, and that the ash portion was alone derived from the soil. To Saussure we owe the first definite statement on the different sources of the plant's food. It may be said that the lapse of nearly a century has shown his views to be, in the main, correct.

Source of Plant-nitrogen.

There was one question, which, even at that remote period in the history of the subject, engaged the attention of agricultural chemists—viz., the question of the source of the plant's *nitrogen*—a question which may

be fitly described at the present hour as still the burning question of agricultural chemistry.¹

As soon as it was discovered that nitrogen was a constituent of the plant's substance, speculations as to its source were indulged in. The fact that the air furnished an unlimited storehouse of this valuable element, and the analogy of the absorption of carbon (from the same source by plant-leaves), naturally suggested to the minds of early inquirers that the free nitrogen of the air was the source of the plant's nitrogen. As, however, no direct experiments could be adduced to prove this theory, and as, moreover, nitrogen was found in the soil, and seemed to be a necessary ingredient of all fertile soils, the opinion that the soil was the only source gradually supplanted the older theory. Little value, however, must be attached to these early theories, as they can scarcely be said to have been based on experiments of serious value. Indeed it may be safely affirmed, in the light of subsequent experiments, that it was impossible for this question to be decided at this early period, from the fact that analytical apparatus, of a sufficiently delicate nature, was then wholly unknown. Indeed it is only within the last few years that it has been possible to carry out experiments which may be regarded as at all crucial. A short sketch of the development of our knowledge of the relation of nitrogen to the plant will be given further on.

¹ See p. 40 to 45.

- Cress, experiments with, 41.
 Crimea, bones from, 360.
 Cropped soils, nitrates in, 157—lost by drainage in, 141.
 Crops, capacity of, for assimilating manures, 486; difference in root-systems of, 488; manuring of common farm, 493-530; period of growth of, 489; potash removed in, 218; suited for sewage, 434; variation in composition of, 490.
 Crusius on phosphoric acid removed from the farm, 207.
 Crust guanos, 308, 379.
 Crystalloids, 491.
 Curaçao phosphates, 308, 330, 379.
- Darmstadt experiments with basic slag, 410-413.
 Darwin on origin of nitrate-fields, 335.
 Daubeny on mineral sources of phosphoric acid, 200.
 Davy, Sir Humphry, lectures of, on agricultural chemistry, 17-19; on heat and water absorbing and retaining properties of soils, 57; on hygroscopic power of soils, 99.
 Dehérain, on nitrification, 52; on nitrification in sulphate of ammonia, 191; on rate of nitrification, 186.
 Denitrification, 177; conditions favourable for, 178; effected by bacteria, 178.
 Derby, Lord, introduction of Peruvian guano by, 301.
 Detmer on humus in soil, 47.
 Dew, action of, on guano, 300; explanation of, 77; most abundant in summer, 78.
 Dicalcic phosphate, 387; formula of, 398; molecular composition of, 398; percentage composition of, 398.
 Digby, Sir Kenelm, on value of nitrates to plants, 45; theory of, on plant-food, 6-8.
 Diorite, phosphoric acid in, 202, 211.
 Direct manures, 113.
 Dissolved-bone compound, 372.
 Dissolved bones, 368; composition of, 371.
 Dissolved guano, 310.
 Dolerite, phosphoric acid in, 202, 211.
- Dolomite, phosphoric acid in, 202, 211.
 Downton experiments on sewage-sludge, 439.
 Drainage, average of thirteen years, 160; nitrates in, 160; nitrates lost by, 140; phosphoric acid lost by, 206; potash lost by, 217.
 Drainings of manure-heaps, analysis of, 290.
 Dried blood, 424; composition of, 424; manure for sugar-cane, 425; potash in, 219; rate of nitrification in, 192; source of nitrogen, 152; suited for horticulture, 425.
 Dried flesh, 425; nitrogen in, 425.
 Dried leaves, as litter, 242; composition of, 242; nitrogen in, 242; phosphoric acid in, 242; potash in, 242.
 Ducks' dung, analysis of, 331.
 Duhamel and Hales, theory of, on plant-growth, 8.
 Dundonald, Earl, treatise by, on agricultural chemistry, 13.
 Dung and urine, composition of, 234.
 Dutrochet on absorption of plant-food, 55.
 Dyer, Dr Bernard, analyses of stable manure by, 283; experiments on peat as litter, 240; on nitrate of soda as manure for mangolds, 349.
- Earth, an adulterant of guano, 319; composition of solid crust of, 102.
 Ecuador, guano deposits at, 327.
 Egyptian guano, nitrogen in, 329; phosphoric acid in, 329.
 Elbe, waters of, phosphoric acid in, 206; potash in, 217.
 Elm-tree, water transpired by, 71.
 Enderbury Island guano, 309, 328; phosphoric acid in, 328.
 Endosmosis, 55.
 English farming, 86.
 Equalised guano, 311.
 Essex, coprolites from, 374.
 Estremadura phosphate, 375.
 Ethylamine, nitrification in, 182.
 Evaporation from soil, 71, 72, 98.
 Excreta, amount of nitrogen in, 149, 292; composition of, 226, 292; difference in amount of, for food con-

- sumed, 279; liquid, in farmyard manure, 224; solid, in farmyard manure, 224; solid, undigested food in, 224; solid, voided by cows, 280, 292; solid, voided by horse, 292; solid, voided by oxen, 280; solid, voided by sheep, 280, 292.
- Factors for calculating manurial ingredients into their different compounds, 553.
- Falkland guano, 308; nitrogen in, 330; phosphoric acid in, 330.
- Fallow-fields, nitrates formed in, 188.
- Fanning Island guano, 328; phosphoric acid in, 330.
- Farmyard manure, 223-292; action of, on soils, 273; ammonia in, 258; amount produced on farm per year, 252; analyses of, 259, 286; application of, 264; ash of, 287, 288; carbonic acid gas in, 258; classes of constituents of, 224; compared with artificials, 476; composition of, 259; denitrification in, 179; depth to plough to, 267; effect of, on potatoes, 520; fertilising matter in, 270; fire-fang in, 264; fresh, composition of, 286, 288; functions of, 268; heat in fermentation of, 78, 253; humates in, 259; humic acid in, 258; inadequate source of nitrogen to soil, 271; indirect influence of, 273; influence of, on soil, 475; Lawes, Sir John, on composition of, 291; Lord Kinaird's experiments with, 289; marsh-gas in, 258; mineral matter in, 260; moisture in, 260; nitric acid in, 259; nitrogen in, 260; ratio of, to ash ingredients, 271; organic matter in, 260; phosphorated hydrogen in, 258; phosphoric acid in, 260; potash in, 260; products of decomposition of, 257; rate of application of, 275; retrogression of nitrogen in, 142; rotten, composition of, 287, 288—value of, 261; rotting, effects of, on, 262; solid excreta in, 224; sulphuretted hydrogen in, 258; supplemented with nitrogen, 271; supplemented with phosphoric acid, 272; temperature, effect of, on soil, 79, 274; typical compost, 446; ulmates in, 259; ulmic acid in, 258; unfavourable to certain crops, 477; urine in, 228; value of, 268; variation in composition of, 223; water in, 258.
- Fatty acids in guano, 305.
- Felspars, 103; albite, 103; composition of, 103; labradorite, 220; oligoclase, 103, 214, 220; orthoclase, 103, 214, 220; phosphoric acid in, 211; potash manures, 213; potash in, percentage of, 213, 220.
- Ferment, aerobic, 173, 255; anaerobic, 255.
- Fermentation, ammonium carbonate formed during, 245; in bones, 365; heat of, 79; of farmyard manure, 253; of guano, 299; temperature of, 256.
- Fern, bracken, as litter, 241.
- Ferric chloride, test for sulphocyanates, 355.
- Fertilisers and Feeding Stuffs Act, 543.
- Fertilising ingredients, amount of soluble, in soil, 90; amounts removed by different crops, 484, 485; chemical condition of, in soil, 89; lodge in seed, 491; in soil, 87.
- Fertility, of the soil, 65-97; potential, of soil, 214, 549; properties necessary for, 66; supply of oxygen necessary for, 81.
- Field experiments, 545, 548; educational value of, 547; on rate of nitrification, 187.
- Finger-and-toe prevented by lime, 461.
- Fire-fang in farmyard manure, 264.
- Fischer on absorption of plant-food, 55.
- Fish-guano, 320-323; application of, 323; consumption of, 152; manufacture of, 321; nitrogen in, 321; phosphoric acid in, 321; production of, 322; source of nitrogen, 152; value of, 322.
- Fixers, 246; chemical reactions with, 284.
- Fleece, potash in, 217.
- Fleischer, Professor, on solubility of phosphates, 408.
- Flesh-guano, 320.
- Flint Island guano, 309.

- Flitcham experiments on growth of wheat, 500.
- Floated bones, 362, 365.
- Florida phosphate, 378.
- Fluorapatite, composition of, 210.
- Food, consumed by pigs, 281; dry matter of, voided in dung, 228; percentage of, in excrements, 281.
- Food-constituents, plant, necessary for nitrification, 170.
- Forbes, David, on nitrate-fields of Chili, 334.
- Forest-soils, absence of nitrification in, 193.
- Fowl-dung, 320, 326; analysis of, 331.
- Fownes on phosphoric acid in rocks, 202.
- Frankland, P. F., experiments on nitrification, 52, 167, 198.
- Franklin, Benjamin, experiment of, with gypsum, 462.
- Frey Bentos, meat-meal guano from, 324.
- Galapagos Islands, guano deposits at, 327.
- Garden earth, absorptive power of, 98; ammonia in, 128.
- Gas-liquor, ammonia in, 353.
- Gas-works, ammonia from, 353, 358.
- Gases, absorbed by soils, 81; present in soil, 100.
- Gazzeri on retention by soil of plant-food, 57.
- Geese-dung, analysis of, 331.
- Geic acid in humus, 47.
- Gelatin, nitrification in, 182; from bones, 364.
- Germany, agricultural research in, 32; bones imported from, 360; manufacture of meat-meal guano in, 324.
- Germination, influence of temperature on, 76; oxygen necessary for, 81.
- Gilbert, Sir J. Henry, on barley-manuring, 496; on Liebig's mineral theory, 28; on manuring of potatoes, 520; Presidential address of, 61; and see Lawes and Gilbert.
- Glauber on artificial production of nitre, 164.
- Glue, 364.
- Glycin, assimilated by plants, 47.
- Glycocoll, experiments with, 46.
- Gneiss, 106; phosphoric acid in, 207.
- Grandeau, Professor, on forms of plant-food in soil, 107; on loss of phosphoric acid, 207.
- Granite, 105; in guano, 303; phosphoric acid in, 202, 211; potash in, 214.
- Grass, Bangor experiments on, 508; effect of manure on, 505; influence of farmyard manure on, 506; manuring of, 504-510.
- Gray, Asa, on transpiration by plants, 71.
- Great Cayman guano, 379.
- Green manures, 113.
- Grouven on guano, 313.
- Guanape Island guano, 302, 327; nitrogen in, 329; phosphoric acid in, 329.
- Guanine, 304; experiments with, 46.
- Guano, 293-331; action of, as a manure, 312; adulteration of, 318; application of, 315; bat, 325; composition of, 305, 329; crust, 308; deposits of the world, 327; dissolved, 310; equalised, 309; fermentation of, 299; fertilising constituents in, 314; fish, 320-323; importance of, in agriculture, 293; inequality in composition of, 309; influence of, on farming, 294; meat-meal, 324; mode of application of, 315; nitrification in, rate of, 192; nitrogenous, 300-308; origin of, 297; Peruvian, 300-306; phosphatic, 308; quantity to apply, 317; rectified, 311; so-called, 320; source of phosphoric acid, 202; source of potash, 219; value of, as a manure, 296; variation in composition of, 299.
- Gulf of Mexico, guano deposits at, 328.
- Gulls, guano from, 297.
- Gunning on sources of plant-nitrogen, 42.
- Gunpowder, exports of, 149; nitrogen lost in, 149; production, annual, of, 149; saltpetre in, 149, 333.
- Gypsum, 462-464; absorptive power of, 98; action of, mode of, 462—on nitrification, 173; an adulterant of guano, 319; as a fixer, 246, 247,

- 285; decomposes double silicates, 463; favourable to clover, 464; as an oxidising agent, 464.
- Hales, Stephen, theory of, on plant-growth, 8.
- Hampe, Dr, on nitrogen in plants, 46.
- Harting on sources of plant-nitrogen, 42.
- Heat, of soils, 76-78; of fermentation, 78.
- Heiden, Dr, on application of farmyard manure, 265; on fixation of bases and acids by soil, 59; on loss of ammonia from dung, 249; on percentage of food voided by animals, 253; on straw as litter, 244, 249.
- Hellriegel, on amount of water in soils, 75; on barley, 498; on nitrogen in plants, 44.
- Helmont, Van, theory of, on source of plant-food, 4.
- Henslow, Professor, on coprolites, 374.
- Heraus on organisms in soil, 95.
- Herbage, effect of manure on, 505.
- Herrings as manure, 321.
- Hervé-Mangon, experiments on action of light on plants by, 38.
- Hilgenstock on tetracalcic phosphate, 405.
- Hippuric acid, experiments with, 46; in farmyard manure, 257.
- Hire, De la, on evolution of gases by plants, 11.
- Hofmeister on horse excrements, 243.
- Hoof-guano, source of nitrogen, 152.
- Hoofs and horns, manure from, 425.
- Hops, manuring of, 528; potash removed by, 217; slow-acting manures benefit, 528.
- Horn, capable of nitrification, 182; as manure, 425; nitrogen in, 426; phosphoric acid in, 426.
- Hornblende, 105.
- Horse-dung, alkalies in, 226; composition of, in dry state, 227; hot, 225; nitrogen in, 225, 226; phosphoric acid in, 226; water in, 225, 226.
- Horse-manure, 242; amount produced per day, 243; amount produced per year, 243; analyses of, 283; dry matter in, 243; dry nature of, 245; fermentation rapid in, 245; mineral matter in, 243; nitrogen in, 243, 244.
- Horse-urine, alkalies in, 230; composition of, in dry state, 231; fertilising ingredients in, 232; nitrogen in, 230; phosphoric acid in, 230; water in, 230.
- Hosäus on assimilation of ammonia, 50.
- Howland Island guano, 309, 328; phosphoric acid in, 330.
- Huanillos, guano from, 302, 327; nitrogen in, 330; phosphoric acid in, 330.
- Huano, 297.
- Hueppe on organisms in soil, 95.
- Hughes, John, on bracken-fern as litter, 241; on composition of bracken, 283.
- Humates in farmyard manure, 259.
- Humboldt, A., discovery of Peruvian guano by, 300.
- Humic acid in farmyard manure, 258; in humus, 47.
- Humin in humus, 47.
- Humus, absorptive power of, 68, 98; evaporation from, 99; nature of, in soil, 47; soils improved by addition of, 273.
- Huon Island guano, 309, 328; phosphoric acid in, 330.
- Huxtable and Thompson on retention of plant-food by soil, 57.
- Hydrated silicates, 107, 459.
- Hydrochloric acid as a fixer, 245.
- Hydrogen, amount of, in plants, 40; source of, in plants, 40.
- Hygroscopic power of soils, 75.
- Ichaboe guano, 307; nitrogen in, 329; phosphoric acid in, 329.
- Independence Bay guano, 302, 327; nitrogen in, 329; phosphoric acid in, 329.
- India, nitre soils of, 162.
- Indirect manures, 113, 114, 449-473.
- Ingenhousz, John, experiments by, on nitrogen in plants, 41; on oxygen evolved by plants, 12.
- Insoluble phosphate, 386; value of, 396.
- Iodine, in ash of plants, 55; in nitrate of soda, 340, 342.

- Iquique, nitrate of soda from, 333.
- Iron in ash of plants, 54; necessary for plant-growth, 55; reversion in superphosphates caused by, 390, 399.
- Iron-works, ammonia from, 353, 355, 358.
- Irrigation, 431-433; intermittent, 434; subsoil, 432.
- Jamieson, Professor, experiments with coprolites, 380.
- Jarvis Island guano, 309, 328; phosphoric acid in, 330.
- Jersey, manuring of potatoes in, 521.
- Johnson, Professor S. W., on application of superphosphate, 395; on Earl Dundonald, 13; on nitrogen in buffalo-horn shavings, 426; on nitrogen in soils, 123; on solubility of basic slag, 408; value of organic nitrogen to plant, 46.
- Jürgensen on nitrogen in excreta, 234.
- Kainit, as a fixer, 247; potash in, percentage of, 214, 220, 421; rate of application of, 423.
- Kaolin clay, analysis of, 104.
- Karmrodt, analysis of Chincha Island guano, 305; of concretionary nodules, 328.
- Karnallite, potash in, 220.
- Kellner, experiments on nitrification by, 52.
- Kelp, potash in, 420.
- Kieserite, 420.
- Kinnaird, Lord, experiments by, with farmyard manure, 289.
- Kitchen-garden soil, nitrogenous matter in, 122.
- Knop on condition of nitrates in soil, 138.
- Koosaw River, phosphates from, 376.
- Kreatin assimilated by plants, 47.
- Kuria Muria guano, 309, 328.
- Labrador, guano deposits at, 328.
- Labradorite, 214; potash in, 220.
- Lacepede Island guano, 309, 328; phosphoric acid in, 330.
- Lahn phosphate, 379.
- Lava, phosphoric acid in, 202, 211.
- Lawes, Sir J. B., and Gilbert, early researches of, at Rothamsted, 34; experiments with farmyard manure, 271; experiments with Peruvian guano, 301; inauguration of Rothamsted experiments by, 33; on composition of farmyard manure, 291; on manuring of wheat, 483; on motion of plant's sap, 56; on percentage of food in excreta, 233; on rate of nitrification, 186; on sources of plant-nitrogen, 43; on sulphate of ammonia, 356; on unexhausted manures, 550, 557-559.
- Lawes, Sir J. B., experiments with guano by, 301; manufacture of superphosphate by, 382; on application of superphosphate, 395; on bones, 359; on composition of farmyard manure, 291; on farmyard manure, 477; on loss of nitrates, 142; on sources of nitrogen, 154.
- Leather, as manure, 428; nitrogen in, 428.
- Leaves, dried, as litter, 242; nitrogen in, 242; phosphoric acid in, 242; potash in, 242.
- Legrange, Charles, on extent of nitrate-fields, 343.
- Leguminous plants, benefited by basic slag, 414—by potash, 523; fixation of free nitrogen by, 42; gain of nitrogen with, 135; manuring of, 522-527, 530; nitrogenous manures hurtful to, 523.
- Lehmann on ammonia as plant-food, 50, 352.
- Leipzig, bones from, 361.
- Leones, guano deposits at, 327.
- Leucite, potash in, 220.
- Lias chalk, phosphoric acid in, 211.
- Liebig, criticism of humus theory by, 25; dissolved bones discovered by, 361; first report to British Association, 24; manufacture of superphosphate from bones by, 359; mineral theory of, 26-29; on ammonia as a manure, 352; on importation of bones by Britain, 360; researches of, in agricultural chemistry, 23-32; services of, to agricultural chemistry, 31; theory of manures by, 29; theory of, on rotation of crops, 29.
- Light, action of, on plant-growth, 38.

- Lime, 449-461; abundant occurrence of, 452; action of, 461—contradictory, 450—not thoroughly understood, 449—on nitrogenous organic matter, 460—on soil's texture, 455; antiquity of, as a manure, 449; binding effect of, 457; biological action of, 459; caustic, 453; chemical action of, 457; decomposes minerals, 458; different forms of, 453; effect of, on soils, 112; fixed by soils, 58; in ash of plants, 54; mechanical functions of, 455; mild, 453; necessary for nitrification, 171, 459—for plant-growth, 55, 450; neutralises acidity in soils, 458; phosphates of, 385-388; pig excrements contain, 281; prevents clay puddling, 456; returned to soil, 452; soils contain, 450-452.
- Limestone, analyses of, 106; evaporation of water from, 99; occurrence of, 452.
- Linseed, imports of, 153; manurial constituents of, 282.
- Linseed-cake, manurial constituents of, 282.
- Liquid manure, 442-444.
- Lithia in ash of plants, 55.
- Litter, loam as, 239; peat as, 240; straw as, 236; uses of, 236.
- Lloyd on fattening animals, 253.
- Loam, as litter, 239; evaporation of water from, 99; poor in fertilising matter, 239.
- Lobos, guano deposits at, 327.
- Lobos de Afuera guano, 302, 327.
- Macabi Island guano, 302, 327; nitrogen in, 329; phosphoric acid in, 329.
- Maercker, Professor, on destruction of nitrifying organisms, 177.
- Magnesia, fixed by soils, 58; in ash of plants, 54; in pig excrements, 281; necessary for nitrification, 171; necessary for plant-growth, 55; sulphate of, as a fixer, 246, 285.
- Maize, absorbs ammonia, 352; fertilising ingredients removed from soil by, 485; manurial constituents in, 282; source of nitrogen, 153.
- Malden Island guano, 309, 328; phosphoric acid in, 330.
- Malpighi on importance of atmospheric air for germination, 39.
- Malt-dust, manurial constituents in, 282.
- Manganese, oxide of, in ash of plants, 54.
- Mangels, fertilising ingredients removed from soil by, 485; guano a manure for, 318; manurial constituents in, 282; manuring of, 346, 511, 513, 514; Rothamsted experiments on growth of, 568.
- Manitoba soils, nitrogen in, at various depths, 156; rate of nitrification in, 186.
- Manure, cow, 247; farmyard, 223-292; horse, 243; liquid, 442-444; meaning of word, 109; pig, 250; sewage, 430-441; sheep, 251; stable, from peat-moss, 283—wheat-straw, 283.
- Manures, action of, 61; analysis of, interpretation of, 539-544; application of, 474-492; method of, 531-538; cash prices of, 555; equal distribution of, 531; functions of, 109; increase soil-fertility, 474; intrinsic value of, 545; lasting effects of, 483; methods of valuing, 544; minor artificial, 424-429; mixing of, 531-538; nitrogenous, 293-359; phosphatic, 359-417; potassic, 418-423; quantities of, applied to oats, 504; unexhausted, 549-552, 558; units for determining commercial value of, 554; valuation of, 539-559; value of, deduced from experiments, 548; various classes of, 111-114.
- Manurial constituents of various foods, 282.
- Manurial ingredients, unit value of, 544.
- Manuring of, barley, 495-498; beans, 525-527, 530; cabbages, 528; cereals, 493-504; clover, 524; common farm crops, 493-530; grass, 504-510; hops, 528; leguminous crops, 522-528; mangels, 511, 513, 514; oats, 493-504; peas, 527; potatoes, 517-522; roots, 510-517; turnips, 510, 511, 513-517; wheat, 499-501.

- Maracaibo guano, nitrogen in, 330 ; phosphoric acid in, 330.
- Marl, phosphoric acid in, 211.
- Marsh-gas from farmyard manure, 258.
- Meadow-hay, fertilising ingredients removed from soil by, 485 ; manurial constituents in, 282 ; Rothamsted experiments on manuring of, 570.
- Meadow-land, benefited by basic slag, 414, 508 ; manuring of, 508 ; Norfolk experiments on, 509.
- Meat-meal guano, 320, 324 ; composition of, 152 ; imports of, 324 ; manufacture of, 324 ; nitrogen in, 324 ; phosphoric acid in, 324 ; rate of nitrification in, 192 ; source of nitrogen, 152 ; value of, 324.
- Mechi on liquid manure, 442.
- Mejillones guano, 309, 327 ; phosphoric acid in, 330.
- Mène, on sources of plant-nitrogen, 42.
- Menhaddo, guano manufactured from, 322.
- Mexico phosphate, 308, 328.
- Mica, analysis of, 105 ; potash in, 214, 220.
- Micro-organisms, convert ammonia into nitrous acid, 167 ; convert nitrous acid into nitric acid, 168 ; effect fermentation, 80 ; effect fixation of free nitrogen, 44 ; effect nitrification, 161 ; oxidising power of, 197.
- Mild lime, 453.
- Milk, nitrification in albuminoids of, 182 ; nitrogen removed in, 147 ; phosphoric acid removed in, 207 ; potash removed in, 218.
- Mineral phosphates, 373-381 ; value of, as a manure, 380.
- Mineral salts necessary for nitrification, 52.
- Minor artificial manures, 424-429.
- Mixing manures, 532-538 ; ammonia lost in, 533 ; nitric acid lost in, 536 ; phosphates reverted in, 536.
- Moisture, atmospheric, action on guano, 300 ; in farmyard manure, 260 ; in manures, 543 ; necessary for nitrification, 52, 176.
- Molds, 94.
- Mona guano, 309.
- Mond, Ludwig, on nitrogen in coal, 354.
- Monks guano, 327 ; phosphoric acid in, 330.
- Monocalcic phosphate, 386 ; formula of, 398 ; molecular composition of, 398 ; percentage composition of, 398 ; reversion of, with iron and alumina compounds, 399 — with tricalcic phosphate, 399.
- Mulder on humus in soil, 47, 126.
- Müller, A., on nitrogen in soil, 121, 124.
- Munro, Dr J. M. H., on nitrification, 52 ; on sewage-sludge as manure, 439 ; on urine voided, 292.
- Muntz, on ammonia in air, 118 ; on nitrifying organisms in soil, 180 ; on oxidising power of micro-organisms, 197.
- Muriate of potash, application of, 423 ; forms calcium chloride, 422 ; harmful effects of, 421 ; more concentrated than sulphate, 422.
- Mustard, 139.
- Navassa phosphate, 308, 328, 379.
- Nesbit on composition of guano, 301.
- New Granada, guano deposits at, 327.
- New Zealand, meat-meal guano from, 324.
- Nile, nitrates in waters of, 159.
- "Nitraries," 163.
- Nitrate-fields, appearance of, 340 ; origin of, 334.
- Nitrate of soda, 332-351 ; amount exported from Chili, 151, 332, 351 ; amount imported into Britain, 151, 351 ; appearance of fields of, 340 ; application of, 347 ; Chili and Peru chief source of, 161 ; composition of, 343 ; crops suited by, 346 ; discovery of deposits of, 333 ; extent of deposits of, 342 ; encourages deep roots, 344 ; formation of fields of, 334-340 ; method of applying, 347 ; method of mining, 341 ; nitric acid in, source of, 337 ; nitrogen in, percentage of, 343 ; not an exhausting manure, 345 ; origin of fields of, 334 ; properties of, 343 ; quantity to apply, 348 ; shipments of, 351 ; soils benefited by, 348 ; source of

- nitrogen, 150; top-dressing with, 344.
- Nitrates, amount lost by drainage, 140; amount produced at different times, 189; amount in soil, 129; conditions diminishing loss of, 139; constantly formed in soil, 138; in barley-soils, 158; in cropped soils, 130, 157; in drainage-waters, 160, 188; in fallow-soils, 129; in manured wheat-soils, 131, 157; in soil, 129, 162; lost by drainage, 137; most formed in summer, 139; nitrogen as, in Rothamsted soils, 198; position of, in soil, 188; quantity formed in fallow-fields, 188.
- Nitre, beds, 163; occurrence of, 162; soils of India, 162.
- Nitric acid, amount of, supplied to soil by rain, 155; derived from seaweed, 337; formed from ammonia, 118; formed from nitrous acid, 168; in farmyard manure, 259; in soil, 128; lost in mixing manures, 536; most important nitrogen compound for plants, 161; relation of, to plants, 50; source of, in nitrate of soda, 337.
- Nitrification, 51, 52, 161-198; action of gypsum on, 173; alkalinity necessary for, 172; in asparagin, 182; bearing of, on agriculture, 193; in bones, 182; cause of, 165; conditions favourable for, 170; denitrification, 177-179; effected by micro-organisms, 51, 167; in ethylamine, 182; in fallow-fields, 184; food-constituents necessary for, 170; field experiments on rate of, 187; in gelatin, 182; in horn, 182; laboratory experiments on rate of, 185; in manures, 190, 192; in milk albuminoids, 182; mineral salts necessary for, 52; moisture necessary for, 52, 176; old theories on, 196; organic matter not necessary for, 169, 196; oxygen necessary for, 52, 173; plant-roots promote, 181; in rape-cake, 182; rate of, 183; rotation of crops, bearing of, on, 195; soil best suited for, 192; in subsoils, conditions favourable for, 181; substances capable of, 181; in summer, 183; sunlight, effect of, on, 176; temperature necessary for, 52, 175; in thiocyanates, 182; in urea, 182; in wool, 182.
- Nitrifying organisms, depth found at in soil, 180; distribution of, in soil, 179; effect of poisons on, 176; organic matter not required by, 169.
- Nitrobaeter*, 167.
- Nitrogen, 115-160; absorbed by soil, 81, 131; accumulates in pastures, 134; in air, 116; as ammonia in soils, 127; amount of, in plants, 40; amount of, in soil, 123; artificial supply of, 150; in bat guano, 325; in bones, 363, 364; combined, in air, 118; combined, in rain, 119, 155; condition of, in manures, 540; converted into nitrates in soil, 51; in cow-dung, 226-228; in cow excrements, 278; in cow-urine, 230; difference between surface and subsoil, 126; different forms of, 45, 116; dissolved in rain, 131; in dried blood, 424; in farmyard manure, 260; in fish-guano, 321; fixation of free, 136; forms of, in plants, 491; free, relation of, to plant, 117; gain of, with leguminous crops, 135; in guanos, 329; in hoofs and horns, 426; in horse-dung, 226-228; in horse-manure, 243; in horse-urine, 230; importance of, in soil, 88; in lean flesh, 424; in leather, 428; least abundant of manurial ingredients in soil, 271; loss of, artificial sources of, 144; loss of, by crops, 144; loss of, on farm, 146; loss of, sources of, 137-150; loss of, total amount of, 142; lost in the arts, 148; lost in free condition, 141; lost in treating farmyard manure, 146; lost in milk, 147; lost by retrogression, 142; in Manitoba soils, 156; in meat-guano, 324; nature of, in soil, 124; as nitrates in soil, 128; as nitrates in cropped soils, 130, 157; as nitrates in Rothamsted soils, 198; as nitrates in wheat-soils, 157; in nitrate of soda, 343; nitric, in soil, 128; organic, absorbed by plants, 47; organic, in soil, 125; original

- source of, in soil, 133; in oxen excrements, 280; in pasture-lands, 158; peat-soils richest in, 123; in Peruvian guano, 302, 306, 307, 329; in pig-dung, 226-227; position of, in agriculture, 115-160; relative manurial value of, 556; Rothamsted experiments on, 115; in scutch, 427; in sewage, 431; in sewage-sludge, 439; in sheep-dung, 226-228; in sheep excrements, 280; in sheep-urine, 230; in soil, 120; in soil, portion of, easily nitrifiable, 187; in soils at various depths, 156; in soot, 428; source of, in plants, 15, 16, 40-52; sources of soil, 131-137; in straw, 237, 243; in subsoil, 121; in surface-soil, 121; in swine-urine, 230; in wool-len rags, 427.
- Nitrogenous guano, 300-308, 329.
- Nitrogenous manures, application of, 478; benefit cereals, 494; hurtful to leguminous crops, 523.
- Nitrogenous organic substances, in Chinchá guano, 305; in concretionary nodules, 328.
- Nitrosomonas*, 167.
- Nitrous acid, converted into nitric acid, 168; formed from ammonia, 167.
- Nobbe, on fixation of free nitrogen, 136; on potash in soil, 108.
- Nöllner on origin of nitrate-fields, 339.
- Norfolk, coprolites from, 374; experiments on barley, 497—on meadow-land, 509—on turnips, 513.
- North America, guano from, 298, 328.
- Norwegian apatite, 375.
- Oak-tree, water transpired by, 71.
- Oat-straw, composition of, 238; manurial constituents in, 282.
- Oats, Arendt's experiments with, 503; avenine in, 503; fertilising ingredients removed from soil by, 485; hardy crop, 502; manurial constituents in, 282; manuring of, 501-504; nitrogen removed in crop of, 148; require mixed nitrogenous manures, 502; source of nitrogen, 153; Rothamsted experiments on growth of, 567.
- Oficinas*, 342.
- Ohlendorff, introduction of dissolved guano by, 311.
- Oilcakes, imports of, 153; source of nitrogen, 153.
- Oil-seeds, source of nitrogen, 153.
- Oligoclase felspars, 103, 214; composition of, 103; potash in, 220.
- Organic matter, in bones, 363; in dung, 228, 260; in manures, 543; not necessary for nitrifying organism, 169.
- Orthoclase felspars, 103, 214; composition of, 103; potash in, 220.
- Ox-dung, fertilising ingredients in, for food consumed, 228.
- Ox-urine, fertilising ingredients in, 232.
- Oxalic acid in guano, action of, 330.
- Oxen, excrements of, 280; food aided by, 280; solid excreta voided by, 280; urine voided by, 280.
- Oxidation, 79; products of, 79, 80.
- Oxygen, absorbed by plant-roots, 81; absorbed by soil, 81; evolved by plants, 11; necessary for fertility, 81; necessary for nitrification, 52, 173; percentage of, in plants, 39; source of, in plants, 39.
- Pabellon de Pica, guano from, 298, 302, 327; nitrogen in, 330; phosphoric acid in, 330.
- Pacific Islands, guano from, 298.
- Pacific Ocean, sea-weed in, 339.
- Palagonite as potash manure, 213.
- Palm-kernel meal, manurial constituents in, 282.
- Pasteur, on fermentation in urine, 255; on nitrification, 166.
- Pastures, accumulation of nitrogen in, 134; benefited by basic slag, 414; deficient in lime, 451; effect of manure on herbage of, 505; nitrogen in, 158; permanent, 138, 194—manuring of, 509; season influences, 507; soil influences, 507.
- Patagonian guano, 308, 327; nitrogen in, 330; phosphoric acid in, 330.
- Patent phosphate meal, 405.
- Patillos, guano deposits at, 327.
- Patos Island, guano deposits at, 328; phosphoric acid in, 330.
- Patterson on superphosphate, 399.

- Payen and Boussingault on composition of dried flesh, 425.
- Peas, manurial constituents in, 282; manuring of, 527; phosphorus in, 205; source of nitrogen, 153.
- Peat, absorbing properties of, 239; adulterant of guano, 317; analysis of stable-manure from, 281; litter, 239; nitrogen in, 240; retaining properties of, 240; soils, 123.
- Pelicans, guano from, 297.
- Penguin Island guano, 330; nitrogen in, 330; phosphoric acid in, 330.
- Penguins, guano from, 297.
- Percival on carbonic acid in plants, 12.
- Peru, guano deposits in, 327; guano first used in, 297; nitrate of soda from, 161, 162.
- Peruvian guano, 300-306; appearance of, 303; composition of, 304-306; deposits of, 301; imports of, 151, 297; source of nitrogen, 151.
- Peters and Eichhorn on solvent power of salt, 471.
- Petzholdt on sources of plant's nitrogen, 42.
- Pfeffer on action of light on plant-growth, 38.
- Phoenix Island guano, 309.
- Phosphate of iron in Chincha guano, 305.
- Phosphate of lime, in Algerian phosphate, 379; in apatite, 374; in Belgian phosphate, 377; in bones, 364; in Cambridge coprolites, 374; in Carolina phosphates, 376; in crust guanos, 379; in Estremadura phosphate, 375; in Florida phosphate, 378; in French phosphates, 379; in Lahn phosphates, 379; in Somme phosphate, 378; reverted in mixing manures, 537.
- Phosphates of lime, 385-388, 398; importance of mechanical condition of, 542.
- Phosphates, mineral, 373-381; imports of, 381; value as a manure, 380.
- Phosphatic guano, 308, 330.
- Phosphatic manures, application of, 480.
- Phosphoretted hydrogen in farmyard manure, 258.
- Phosphoric acid, 199-211; in ash of plants, 54; in basic slag, 404; in bat guano, 325; in bones, 363; condition of, in soil, 203; in cow-dung, 226-228; in cow excrements, 280; in cow-urine, 230; in farmyard manure, 260; in fish-guano, 321; fixed by soils, 58; gain of, 208; in guano, percentage of, 329, 330; guano a source of, 202; in hoofs and horns, 426; in horse-dung, 226-228; in horse-urine, 230; importance of, 88; loss of, artificial sources of, 206—by drainage, 206—in farmyard manure, 208—in milk, 207—in sewage, 208—sources of, in agriculture, 205; in meat-guano, 324; mineral sources of, 200; necessary for plant-growth, 55; occurrence of, in animals, 205—in nature, 199—in plants, 204—in soil, 203; in oxen excrements, 280; in pig-dung, 226, 227; in pig excrements, 281; in pig-urine, 230; position of, in agriculture, 199-211; relative trade values of, in manures, 400; in rocks, 202, 211; in sewage-sludge, 441; in sheep-dung, 226-228; in sheep excrements, 280; in sheep-urine, 230; statement of, in analyses of manures, 541.
- Phosphoric, 201, 374.
- Phosphorus, in albuminoids, 205; in animals, 205; in beans, 205; in peas, 205; in plants, 204; in pig-iron, 401.
- Physical properties of soils, 66-87.
- Pichard on action of gypsum on nitrification, 173.
- Pig-dung, composition of, 226; in dry state, 227.
- Pig excrements, 281; composition of, 281.
- Pig-manure, 250; amount produced per day, 251; mineral matter in, 251; nitrogen in, 251; poor in nitrogen, 251.
- Pig-urine, composition of, 230—in dry state, 231.
- Pigeon-dung, 320, 325; analysis of, 331.
- Pigs, excrements of, 281; food consumed by, 281.
- Pisagua, nitrate-fields at, 340.
- Plant, action of light on, 38; amount

- of hydrogen in, 40—nitrogen in, 40—oxygen in, 40; ash constituents of, 53-55; carbon fixed by, 37, 38; food, absorption of, by, 55; phosphoric acid in, 204; potash in, 216; proximate composition of, 36; relation of ammonia to, 48-50; source of hydrogen in, 40—nitrogen in, 40-52—oxygen in, 39, 40.
- Plant-food, absorption of, 490; amount of soluble, in soil, 100; early theories on source of, 4; retained by soil, 57.
- Plant-roots, grow downwards, 84; nitrification promoted by, 181; openness required by, 83; room required by, 85; soil in relation to, 84.
- Pliny, on lime as a manure, 449; on salt as a manure, 465.
- Pockets a source of phosphoric acid, 202.
- Poisons, effect of, on nitrifying organisms, 176.
- Polstorff on ash constituents of plants, 53.
- Polyhallite, potash in, 220, 420.
- Porphyry, in guano, 303; phosphoric acid in, 202, 211.
- Potash, 212-220, 418-423; in ash of plants, 54; in barilla, 420; chloride of, 218; condition of, in soil, 216; in cows' excrements, 280; in drainage-waters, 217; in farmyard manure, 260; in felspars, 220; in fleece, 217; fixed by soils, 58; importance of, in soil, 88; in kelp, 420; less important than phosphoric acid, 212; manures, 218, 418-423; muriate of, 218, 421; necessary for nitrification, 171; necessary for plant-growth, 55; occurrence of, 213; in ocean, 213; in oxen excrements, 280; in pig excrements, 280; in plants, 216; position of, in agriculture, 212-220; relative manurial value of, 556; Scottish soils supplied with, 419; in sheep excrements, 280; soda replaces, 466; sources of loss of, 217; in Stassfurt salts, 214; statement of, in analyses of manures, 542; in sugar-beet refuse, 219; sulphate of, 218, 421; in wood-ashes, 218, 220, 419.
- Potash manures, 218, 418-423; application of, 422, 480—rate of, 423; barilla as, 420; crops suited for, 423; relative importance of, 418; soils suited for, 423; sources of, 419; Stassfurt salts as, 420; wood-ashes a source of, 419.
- Potassium phosphate in concretionary nodules, 328.
- Potassium sulphate, in Chincha guano, 305; in concretionary nodules, 328.
- Potatoes, effect of farmyard manure on, 520; fertilising ingredients removed from soil by, 485; grown with covered manure, 289; Highland Society's experiments on, 518; manurial constituents in, 282; manuring of, 517-522—in Jersey, 529—influences composition of, 521; potash removed in, 217; Rothamsted experiments on, 519, 571.
- Precipitated ammonium phosphate in concretionary nodules, 328.
- Precipitated phosphate, 330, 387.
- Precipitation, treatment of sewage by, 436.
- Priestley, discovery of evolution of oxygen by plants, 11; on nitrogen in plants, 40.
- Prussiate of potash, manufacture of, 353.
- Pugh on sources of plant-nitrogen, 42.
- Punta de Lobos guano, 302; nitrogen in, 303; phosphoric acid in, 303.
- Punta de Patillos, guano deposits at, 327.
- Pyroxene, potash in, 220.
- Quartz, evaporation of water from, 99.
- Queensland, meat-meal guano from, 324.
- Quercitan, experiments of, with roses, 8.
- Rape-cake, capable of nitrification, 182; manurial constituents in, 282.
- Rape-seeds, imports of, 153.
- Raza Island guano, 328; phosphoric acid, 330.
- Rectified guano, 311.
- Relative trade values of phosphoric acid, 400.

- Resin in guano, 305.
 Retentive power of soils for water, 70-73.
 Retrogression, nitrogen lost by, 142.
 Reverted phosphates, 389-391; determination of amount of, 391; formation of, 387; value of, 391.
 Rhine, nitrates in waters of, 158.
 Rice-meal, an adulterant of guano, 319; manurial constituents of, 282.
 Rocks, phosphoric acid in, 202.
 Roots, influence of manures on composition of, 512; manuring of, 510-522; Norfolk experiments on, 513; potash removed in, 217.
 Rotation of crops, bearing of, on nitrification, 195.
 Rotations, phosphoric acid in, 290; potash removed in, 290.
 Rothamsted, alternate wheat and bean rotation at, 524; ammonia in rain at, 49; barley experiments at, 566; Broadbalk Field, alteration in composition of, 159—manuring of, 159—produce of wheat on, 159; early experiments at, 33-36; experiments, 560-572; experiments with nitrate of soda at, 347; experiments on nitrogen question at, 115—mangel-wurzel, 568—oats, 567—potatoes at, 519—value of nitrogen in farmyard manure, 271; increase of nitrogen with manures at, 137, 513; nitrates in barley-soils of, 158; nitrates in cropped soils of, 130, 157; nitrates in drainage of, 189; nitrates in wheat-soils of, 131, 157; nitrogen as nitrates in soils of, 129, 198; nitrogen, decrease of, in soils, 159; nitrogen in pasture at, 126; pasture, increase of nitrogen in, 158; retrogression of nitrogen at, 142; soil, nature of, 561—nitrogen in, at various depths, 156; total amount of nitrogen lost at, 142; turnip experiments at, 568; unmanured fallow-land loses nitrogen by drainage at, 141; wheat experiments at, 500, 562-565.
 Roy on sources of plant-nitrogen, 42.
 Rubidia in ash of plants, 55.
 Ruffle, John, on superphosphate, 388.
 Rye, manurial constituents in, 282.
 Rye-grass suited for sewage, 435.
 Rye-straw, summer, composition of, 238; winter, composition of, 238.
 St Helena, experiments at, with Peruvian guano, 301.
 Saldanha Bay guano, 328; nitrogen in, 329; phosphoric acid in, 329.
 Salinas, 335.
 Salm-Horstmar, Prince, on water-culture, 54.
 Salt, 465-473; action of, on crops, 472; adulterant of guano, 319; amount applied, 473; antiquity of use of, 465; an antiseptic, 468; application of, 472; clarifies water, 470; coagulates clay, 470; decomposes minerals, 470; a germicide, 468; indirect action of, 468; mechanical action of, 470; nature of action of, 465; not a necessary plant-food, 466; occurrence of, 467; prevents rapid fermentation, 471; quantity to apply, 473; solvent action of, 470; sources of, 468.
 Saltpetre, formation of, 164; occurrence of, 215; plantations, 163.
 Sand, absorptive power of, 68; an adulterant of guano, 319; calcareous, absorptive power of, 98; siliceous, absorptive power of, 98.
 Sandy soils deficient in lime, 451.
 Sandwich Islands, guano deposits at, 328.
 Saragossa Sea, sea-weed in, 339.
 Saussure, De, on absorption of gases by soil, 81; on nitrogen in plants, 41; researches on plant-food by, 15.
 Sawdust an adulterant of guano, 319.
 Scheibler, Professor, on basic slag, 404.
 Schloesing and Müntz, on nitrification, 51, 166; experiments on rate of nitrification by, 185; on denitrification, 179; on ferments effecting nitrification, 167; on fixation of free nitrogen, 42; on ammonia in air, 119, 132; on nitrogen absorbed by soil from air, 132; on temperature favourable for nitrification, 175.
 Schoenite, potash in, 220.
 Schübler, on absorptive power of soils, 98; on retentive power of soils, 98.

- Schulze on fixers, 246.
 Scutch, 427; manufacture of, 427; nitrogen in, 427.
 Sea-weed, nitric acid in, 339.
 Seals, guano from, 297.
 Seed, fertilising ingredients lodge in, 491.
 Seine, nitrates in waters of, 158.
 Sénébier, Jean, on carbon in plants, 12; on nitrogen in plants, 41.
 Sewage, 430-441; charcoal a filter for, 437; crops suited for, 434; denitrification in, 179; dry matter in, 431; effects of continued applications of, 433; filters for, 437; irrigation with, 431-433; nitrification in, 166; nitrogen lost in, 149; phosphoric acid lost in, 149; purified by soils, 435; treatment of, by precipitation, 436; value of, as a manure, 430.
 Sewage-sick land, 433.
 Sewage-sludge, 438-441; as a manure, experiments with, 438; nitrogen in, 439; phosphoric acid in, 439; profitable treatment of, 441; value of, 439; water in, 438.
 Shale-works, sulphate of ammonia, from, 358.
 Shark's Bay guano, 309, 328.
 Sheep, excrements of, 280, 281; solid excreta voided by, 280; urine voided by, 280.
 Sheep-dung, alkalies in, 226; composition of, in dry state, 227; most valuable excrement, 227; nitrogen in, 226; phosphoric acid in, 226; water in, 226.
 Sheep-manure, 251; amount produced per day, 251—per year, 252; dry matter in, 252; mineral matter in, 252; nitrogen in, 252.
 Sheep-urine, alkalies in, 230; composition of, in dry state, 231; most valuable urine, 231; nitrogen in, 230; phosphoric acid in, 230; water in, 230.
 Shoddy, 427; production of, 152, 425; nitrogen in, 152, 427.
 Sicily, bones from, 360.
 Sidney Island guano, phosphoric acid in, 330.
 Siemens, Dr, experiments by, with light on plants, 38.
 Silica, in ash of plants, 55; in Chincha guano, 305; jelly, 169; necessary for plant-growth, 55.
 Silicates, 102; absorbed by cereals, 494.
 Silicic acid fixed by soils, 58.
 Simon on humus in soil, 47.
 Slaked lime, 454.
 Slugs killed by lime, 461.
 Smut prevented by lime, 461.
 Soda, in ash of plants, 54; fixed by soils, 58; necessary for plant-growth, 55; nitrate of, 332-351; in *salinas*, 335; replaces potash, 466.
 Sodium chloride in Chincha Island guano, 305.
 Sodium phosphate in concretionary nodules, 328.
 Sodium sulphate in concretionary nodules, 328.
 Soil, 65-108; absorptive power of, for water, 67, 98; acids fixed by, 58-60; action of lime on, 453; ammonia absorbed by, 81; amount of soluble plant-food in, 100; artificial, 54; barley, nitrates in, 158; bases fixed by, 58-60; best suited for nitrification, 192; biological properties of, 92-96; capacity for heat, 76-78; carbonic acid absorbed by, 81; chemical composition of, 87-92, 101-107; colour of, 80; cropped, nitrates in, 157; denitrification in, 177; evaporation from, 71, 72; farmyard manure, action of, on, 272; fertilising ingredients in, 87; fertility of, 65-108; fineness of, 69-70; gases in, 100; hygroscopic power of, 75-76, 99; improved by humus, 272; influence of farmyard manure on, 475; on nitrification, 180; manures increase fertility of, 474; nitrates in, amount of, 128-131; nitrifying organisms in, 179; distribution of, 179; nitrogen absorbed by, 81, 82, 131; nitrogen accumulates, 133; nitrogen in, amount of, 120-128; nitrogen least abundant of manurial ingredients in, 270; nitrogen at various depths in, 156; oxygen absorbed by, 81; phosphoric acid in, 203—condition of, in, 203—occurrence of, in, 203;

- peat, 123; possesses power of fixing ammonia, 57; potash in, 215—condition of, in, 216; potential fertility of, 549; power of, for absorbing gases, 81; relation of, to plant-roots, 84; retention of plant-food by, 57; retentive power of, for water, 70-73; sewage purified by, 435; shrinkage of, 74; variation in absorbing powers of, 82; varieties of, 67; virgin, 133; water in, most favourable amount of, 75; waterlogged, 179; wheat, nitrates in, 157.
- Soluble phosphate, 386.
- Sombrero phosphate, 308, 328, 330, 379; phosphoric acid in, 330.
- Somme phosphate, 378.
- Soot, 428; application of, rate of, 429; crops suited by, 429; nitrogen in, 428.
- South America, guano deposits in, 327; meat-meal guano from, 324.
- Starbuck Island guano, 309, 328; phosphoric acid in, 330.
- Stassfurt salts, 214; potash in, 215, 420.
- Stead and Ribsdale on formation of basic slag, 407.
- Stoeckhardt, on composition of solid excreta, 226; on composition of urine, 229.
- Storer, Professor, on composition of birds' dung, 331; on composition of leaves, 242; on fish-guano, 323; on nitrogen removed in milk, 147.
- Straw, composition of, 238; imports of, 153; as litter, 236, 248; mineral matter in, 238, 243; nitrogen in, 237, 243; variation in composition of, 237.
- Subsoil, conditions favourable for nitrification in, 181.
- Suffolk coprolites, 374.
- Sugar-beet refuse, potash in, 219.
- Sulphate of alumina, a precipitant of sewage, 437.
- Sulphate of ammonia, 352-358; ammonia in, 355; application of, 356; composition of, 355; a concentrated nitrogenous manure, 356; converted into nitrates, 356; from gas-works, 353; from iron-works, 355; from shale-works, 354; manure for cereals, 356; most easily nitrifiable manure, 191; production of, 151, 358; properties of, 355; source of nitrogen, 149; sources of, 353, 354, 358; sulphocyanate of ammonia in, 355.
- Sulphate of lime a fixer, 246.
- Sulphate of magnesia, an adulterant of guano, 319; as a fixer, 246.
- Sulphate of potash, application of, 422—rate of, 423; compared with muriate, 421; sources of, 218, 420.
- Sulphuretted hydrogen from farm-yard manure, 258.
- Sulphuric acid, action of, on bones, 382—on guano, 311—on tricalcic phosphate, 398; in ash of plants, 54; as a fixer, 245, 285; necessary for plant-growth, 55; superphosphate manufactured with, 384, 388.
- Superphosphate, 382-400; action of, 392-395—sometimes unfavourable, 395; application of, 395—rate of, 397; composition of, 391; discovery of, 382; hastens early growth, 394; high-class, 392; low-class, 392; manufacture of, 383-385—phosphates suitable for, 384; medium-class, 391; production of, 382; reversion in, 389, 399, 400—causes of, 389, 390; reverted in soil, 392.
- Surprise Island guano, 328.
- Swan Island guano, 328.
- Swedes, fertilising ingredients removed from soil by, 485; manurial constituents in, 282; manuring of, 514.
- Swine-dung, alkalies in, 226; composition of, 227; nitrogen in, 226; phosphoric acid in, 226; water in, 226.
- Swine-urine, alkalies in, 230; composition of, 231; nitrogen in, 230; phosphoric acid in, 230; water in, 230.
- Sydney Island guano, 309.
- Syenite, 106; phosphoric acid in, 202, 211.
- Sylvin, potash in, 220.
- Symbiosis*, 44.
- Tamarugal, Pampa de, nitrate deposits in, 340.
- Tarapaca, nitrate deposits in, 340.
- Temperature necessary for nitrification, 52, 175.

- Tetracalcic phosphate, 387; occurrence of, 387, 405; solubility of, 387.
- Thaer on application of farmyard manure, 275.
- Thiocyanates, nitrification in, 182.
- Thomas-Gilchrist process of steel-smelting, 402.
- Thomas-slag. See Basic slag.
- Tillage increases number of plants, 86.
- Timor Island guano, 309.
- Tobacco, potash in, 217.
- Torrefied horn, 426.
- Torrefied leather, 428.
- Tortola guano, 309.
- Trachyte, phosphoric acid in, 202, 211.
- Transpiration, by elm-tree, 71; by oak-tree, 71.
- Trees, as pumping-engines, 76; water transpired by, 71.
- Tricalcic phosphate, 386, 398.
- Tubercles on roots of plants, 44.
- Tull, Jethro, theory of, on plant-growth, 9-11, 69, 109.
- Turkey, dung produced by, 331.
- Turnips, fertilising ingredients removed from soil by, 485; manurial constituents in, 282; manuring of, 510, 511, 513-517; Rothamsted experiments on growth of, 568.
- Twigs, potash in, 217.
- Tyrosin, assimilated by plants, 47.
- Ulmates in farmyard manure, 259.
- Ulmic acid, in farmyard manure, 258; in humus, 47.
- Ulmin in humus, 47.
- Uncovered farmyard manure, 263, 289.
- Unexhausted manures, valuation of, 549-552, 558.
- Unit value of manurial ingredients, 544.
- Units for determining commercial value of manures, 554.
- Urate of ammonium in Chincha Island guano, 305.
- Urea, assimilated by plants, 46; in farmyard manure, 257; nitrification in, 182.
- Uric acid, experiments with, 46; in Chincha Island guano, 305.
- Urine, 228; amount voided, 291; composition of, varies, 228; contains digested manurial ingredients, 228, 232; devoid of phosphoric acid, 205; and dung, composition of, 234; influence of food on, 229; nitrification in, 197; nitrogen in, 292; potash in, 292; voided by cows, 280; voided by oxen, 280; voided by pigs, 281; voided by sheep, 280.
- Uruguay, meat-meal guano from, 324.
- Valuation of manures, 539-559.
- Vegetation, desirable to have soil covered with, 194.
- Venezuela, guano deposits at, 327.
- Ville, Georges, on assimilation of ammonia, 50; theory of, on source of plant-nitrogen, 41.
- Vine, potash removed by, 216.
- Virgin soils, 133.
- Voelcker, Dr, analysis of apatite, 210—of farmyard manure, 259; on action of superphosphate, 395; on fresh and rotted dung, 261, 286; on guano, 316; on salt as a manure, 473.
- Voss, Hermann, on manures used, 152.
- Wagner, Professor, on, application of basic slag, 416; assimilation of organic nitrogen, 46; experiments with basic slag, 403-413; fineness of basic slag, 409; manures, 412; relative manurial value of nitrogen compounds, 556; solubility of basic slag, 408.
- Wallace, Dr, on sewage purification, 436.
- Walruses, guano from, 297.
- Warrington, R., on ammonia in rain, 49; on appearance of nitrous organisms, 168; on conditions favourable for nitrification, 181; experiments on rate of nitrification, 186; on composition of farmyard manure, 260; on manufacture of superphosphate, 383; on manurial constituents of foods, 282; on nitrification in alkaline solutions, 197; on nitrogen in excrements, 233; on nitrogen in soil, 122; on potash in wool, 227; researches of, on nitrification, 35, 52, 166-168, 180, 186.

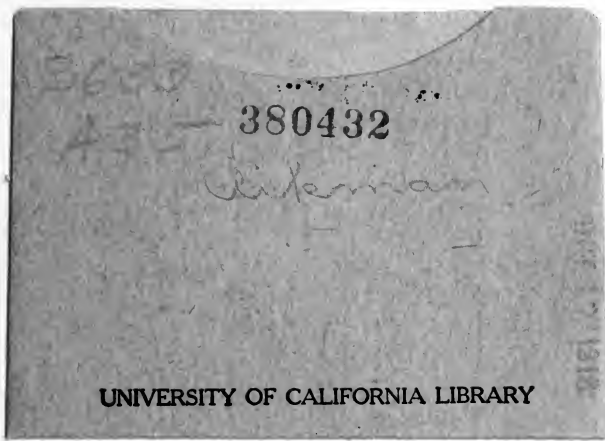
- Water, absorbed by plants, 73 ; amount of, transpired by plant-leaves, 56 ; an adulterant of guano, 319 ; a carrier of plant-food, 55 ; in cow-dung, 226—cow-urine, 230 ; from decomposition of farmyard manure, 257 ; in horse-dung, 226—horse - urine, 230 ; necessary for plant, 67 ; in pig-dung, 226—pig-urine, 230 —sheep - dung, 226—sheep - urine, 230 ; transpired by elm-tree, 71—oak-tree, 71.
- Water-culture, 54.
- Water-logged soils, 179.
- Waterloo, bones from, 360.
- Way, Thomas, on retention of plant-food by soil, 57, 59 ; on sewage, 437.
- West Indies, guano from, 298.
- Whales, guano from, 322.
- Wheat, fertilising ingredients removed from soil by, 485 ; Flitcham experiments on, 500 ; manurial constituents in, 282 ; manuring of, 499-501 ; nitrogen removed in crop of, 145 ; requires nitrogenous manures, 499 ; Rothamsted experiments on, 500, 562-565 ; a source of nitrogen, 153.
- Wheat-soils, nitrates in, 157.
- Wheat-straw, analysis of stable manure made from, 283 ; composition of, 238 ; manurial constituents in, 282.
- White clover, growth of, promoted by lime, 451.
- Wiegmann on ash constituents of plants, 53.
- Wilfarth on nitrogen in plants, 44.
- Wilting, 73.
- Winogradsky, on nitrification, 52, 167, 169, 197 ; on organisms in soil, 94.
- Wolff on, analysis of manure - heap drainings, 290 ; composition of fresh and rotten dung, 288 ; assimilation of organic nitrogen by plants, 47 ; relative manurial value of manurial compounds, 556 ; urine, 232.
- Wood-ashes as potash manure, 218, 419.
- Woodhouse, researches of, on nitrogen in plants, 41.
- Wool, capable of nitrification, 182 ; potash in, 217.
- Wool-waste, 427 ; nitrogen in, 427.
- Woolney, on organisms in soils, 93, 95 ; on water in soils, 75.
- Wrightson, Professor, on application of basic slag, 414.
- Yeast, 94.
- Yorkshire, bones first used in, 359.
- Zeolites, potash in, 220.

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